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NEW YORK STATE MUSEUM

54TH ANNUAL REPORT

OF THE

REGENTS

1900

VOL. 3

MUSEUM BULLETINS 37-44

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University of the State of New York

BULLETIN

OF THE

New York State Museum

FREDERICK J. H. MERRILL *Director*

No. 37 Vol. 8

September 1900

ILLUSTRATED DESCRIPTIVE CATALOGUE

OF SOME OF THE MORE IMPORTANT

INJURIOUS AND BENEFICIAL INSECTS

OF

NEW YORK STATE

By
EPHRAIM PORTER FELT D. Sc.
State entomologist

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This catalogue by no means includes all the injurious insects attacking the classes of plants listed. It gives the more important characteristics of the insects represented in a collection prepared for exhibition at farmers institutes, granges, fairs and other gatherings where it might be advisable to make such a display. The species have also been represented by figures so far as the means at hand would permit. Many of the illustrations have been borrowed from other works, and a few have been made specially for this catalogue.

STAFF

EPHRAIM PORTER FELT
State entomologist
CHARLES S. BANKS
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Assistants

INJURIOUS AND BENEFICIAL INSECTS

FRUIT TREE INSECTS

1 **Apple tree tent-caterpillar** (*Clisiocampa americana*). The conspicuous web tents found in the forks of apple and cherry trees in May contain hairy, bluish black caterpillars marked with yellowish and with a white stripe along the back. The cocoons are spun the last of May, the light brown moths, with oblique white stripes across the fore wings, flying in June. The eggs, in belts incircling the smaller twigs, are covered with a brown, glistening protective substance and remain unhatched till spring.

FIG. 1 Egg belt of apple tree tent-caterpillar, enlarged

Treatment: remove and destroy the eggs or crush the young in their nests. Spray the foliage of infested trees with poison in early spring.

2 **Codling-moth** (*Carpocapsa pomonella*). Familiar as the worm boring in apples near the core. The winter is passed by the caterpillar in small cavities under sheltering bark or in crevices. The moths appear shortly after the petals fall. There are usually two broods a year in New York state.

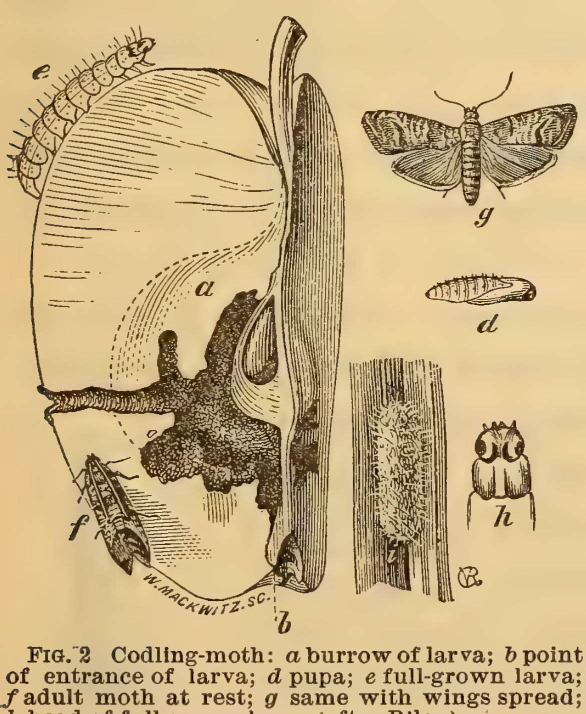


FIG. 2 Codling-moth: *a* burrow of larva; *b* point of entrance of larva; *d* pupa; *e* full-grown larva; *f* adult moth at rest; *g* same with wings spread; *h* head of full-grown larva (after Riley)

Treatment: band trees and kill worms collecting under the bands, destroy wormy apples, spray with poison shortly after the petals have fallen, and while the calyx lobes are still open. Prevent escape of the moths in the spring from fruit cellars or storehouses.

3 **Palmer worm** (*Ypsolophus pometellus*). Small wriggling, yellowish green caterpillars, having a dark stripe on

either side and ornamented with rather conspicuous dark tubercles, were very numerous the latter part of June and early July in many orchards, where they skeletonized the leaves and ate large holes in the young fruit. The parent insect emerges from a slender brown pupal case and is a delicate, grayish moth.

Treatment: spray thoroughly in early June with poison.

4 **Pistol case-bearer** (Coleophora malivorella). Small caterpillars in pistol-shaped cases feed from April to May on the opening flowers and young leaves of the apple tree, often skeletonizing the latter. The dark drab colored moths appear the latter part of June, deposit eggs and the young emerge therefrom the latter part of July. The winter is passed by the caterpillars within cases securely attached to the bark.

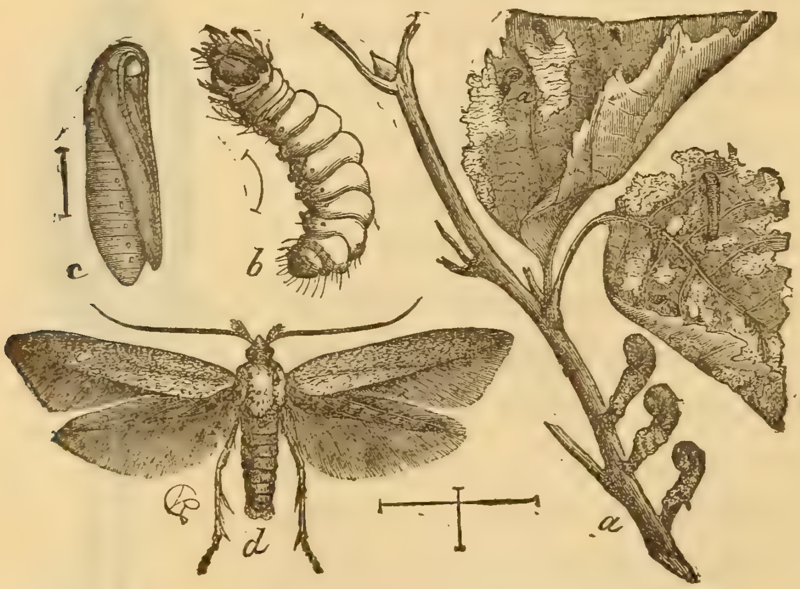


FIG 3 Pistol case-bearer: *a* cases containing the larvae, natural size; *b* larva; *c* pupa; *d* moth; *b*, *c* and *d* enlarged (after Riley)

Treatment: spray infested trees with the poison just as the buds are opening, and repeat, if necessary, a few days to a week later.

5 **Cigar case-bearer** (Coleophora fletcherella). Small caterpillars in cigar-shaped cases feed from April to June on the buds and foliage of apple trees. The delicate, gray moths appear from the middle of June to the middle of July, lay eggs, which hatch in about two weeks, the young being leaf-miners. The caterpillars soon make cases, later attach them securely to the bark, pass the winter therein, and begin feeding again in early spring.

FIG. 4 Cigar case-bearer on bit of leaf—four times natural size (original)

Treatment: spray infested trees with poison just as the buds are opening, and repeat, if necessary, a

few days to a week later. Kerosene emulsion is also effective, if applied at this time.

6 **Bud moth** (*Tmetocera ocellana*). Small brown caterpillars about ½ inch long, with black head and thoracic shield, are frequently found eating the young leaves and flowers of apple and pear tree. The parent moth is an inconspicuous, grayish insect. The winter is passed by the half-grown caterpillars within almost invisible cocoons attached near a bud or rough place in the bark.

FIG. 5 Eye-spotted bud moth and its caterpillar

Treatment: spray thoroughly with poison as the buds begin to open.

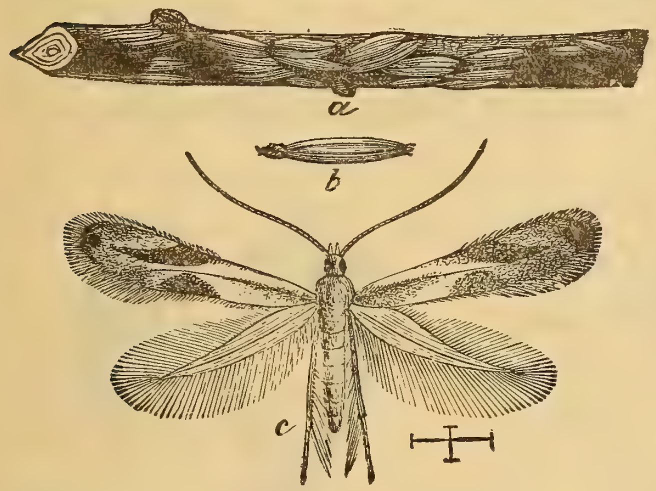


FIG. 6 Apple leaf Bucculatrix: *a* cocoons on twig; *b* cocoon enlarged; *c* moth enlarged

7 **Apple leaf Bucculatrix** (*Bucculatrix pomifoliella*). White, ribbed cocoons about ¼ inch long may be seen in clusters on smaller limbs of infested trees. The parent insect is a delicate moth marked with yellowish and brown. The small larvae mine the leaves and later feed externally. There are two broods annually.

Treatment: spray infested foliage with poison in early June.

8 **Rose beetle** (*Macrodactylus subspinosus*). Greenish yellow beetles about ⅜ inch long appear in swarms in May and attack the foliage of various trees and vines. The young are white grubs and live under ground on grass and the roots of other plants. This insect occurs most abundantly on a sandy soil.

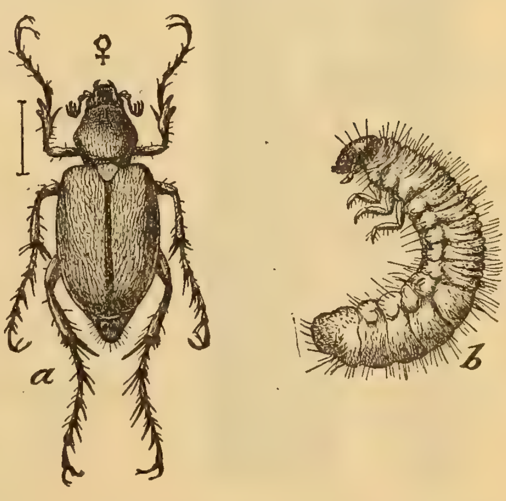


FIG. 7 Rose beetle: *a* adult beetle; *b* larva (reduced after Marlatt. U. S. dep't agr., Yearbook 1895)

Treatment: spray beetles with ½ pound whale oil soap to 1 gallon water, dust vines with ashes, etc.; handpicking.

FIG. 8 Apple tree borer, adult beetle

9 Apple tree borer (*Saperda candida*). The presence of this insect is usually indicated by "sawdust" or diseased bark and beneath the latter, legless, white, round headed borers are found. The brown beetles, striped with white, about 1 inch long, occur from June to August. Two or three years are required to complete the life cycle.

Treatment: protect base of tree with wire netting. Dig out the young borers in the fall. Cut and burn badly infested trees.

10 Pear midge (*Diplosis pyrivora*). The dwarfed, deformed, infested fruit drops early, and within occur thick bodied, pale yellow maggots. The parent midge appears about the time the trees are in bloom and deposits her eggs. The young grow rapidly and cause a distortion of the fruit, which usually cracks with the first good rain about June 1. The larvae then enter the ground and pupate.

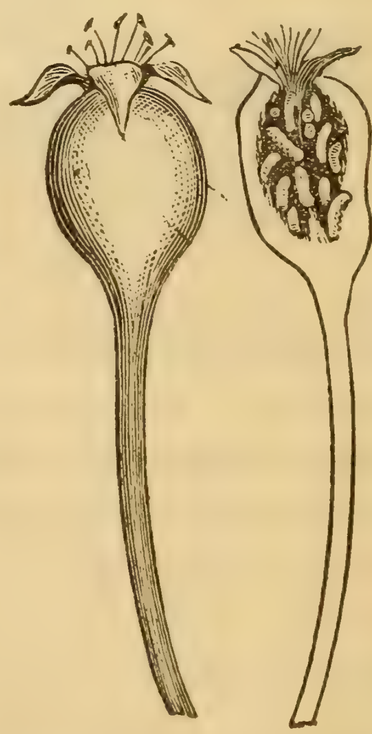


FIG. 9 Pear midge. Section of pear containing the larvae, and an uninfested one for comparison of forms

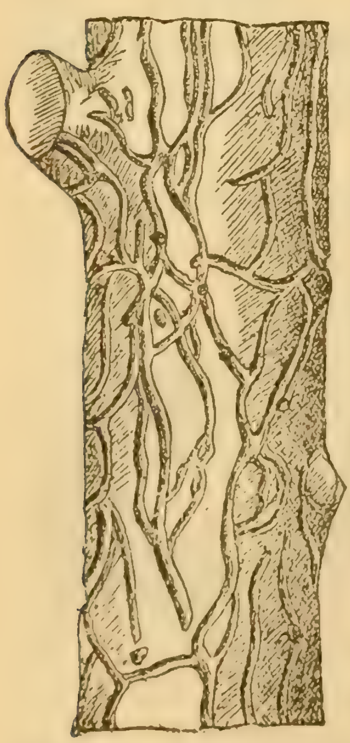


FIG. 10 Burrows of peach bark borer in a young apple tree

Treatment: destroy infested fruit.

11 Peach bark borer (*Scolytus rugulosus*). The bark of affected

trees is punctured with many small, circular holes, made by brownish black beetles less than $\frac{1}{8}$ inch long. The inner portions of the bark and sap wood are frequently filled with burrows. The parent beetles enter the bark and make burrows, on either side of which eggs are deposited, and the young work away from the main burrow. There are probably two broods annually in New York state.

Treatment: burn badly infested trees. Apply carbolic soap wash to trunks and limbs in early spring.

12 **Pear blight beetle** (*Xyleborus dispar*). The bark of affected trees is punctured with many small, circular holes made by dark brown beetles about $\frac{1}{8}$ inch long. Inner portions of the bark and sap wood are filled with burrows.

Treatment: burn badly infested trees.

13 **17 year cicada** (*Cicada septendecim*). Slit and broken twigs with wilting leaves are characteristic of the work of this insect, but unless the trees are small not much damage is done. Broods appear at intervals of 17 years. The adult may be distinguished from the dog day cicada by its bright red eyes and wing veins of the same color.

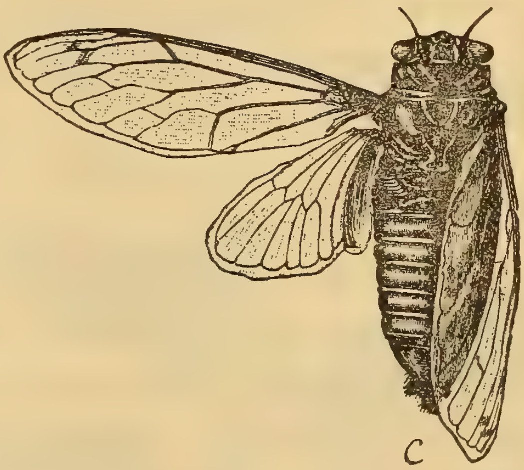


FIG. 11 17 year cicada

Prevention: avoid setting out trees in last few years before cicadas are due.

14 **Apple tree bark louse** (*Mytilaspis pomorum*). Bark infested with elongated brownish scales shaped somewhat like oyster shells. The winter is passed as white eggs under old scales, the young appear about June 1. A common scale insect which sometimes occurs in large numbers, and infests many different shrubs and trees.

Treatment: spray young with kerosene emulsion or whale oil soap solution.

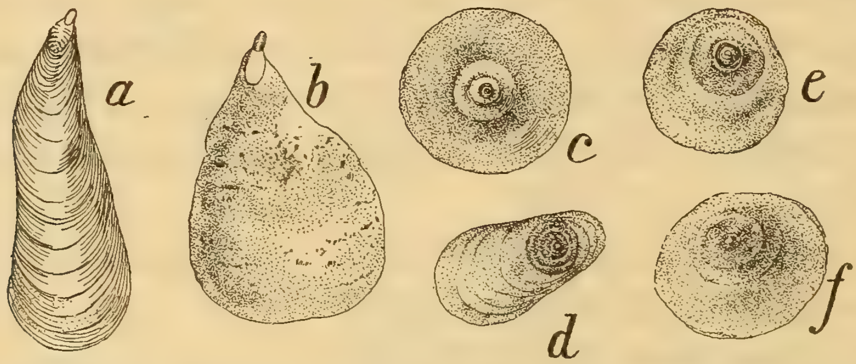


FIG. 12 Scale insects: *a* apple tree bark louse; *b* scurfy bark louse; *c* San José scale; *d* male of same; *e* English oyster scale; *f* Putnam's scale (original)

15 **Scurfy bark louse** (Chionaspis furfurus). The whitish, scurfy scales occur on the bark of fruit trees. The purplish eggs remain under the old scales all winter, the young appearing about June 1. A widely distributed scale insect which is sometimes so abundant as literally to coat the trunk of a tree and give it the appearance of having been whitewashed. It is confined largely to fruit trees.

Treatment: spray young with kerosene emulsion or whale oil soap solution.

16 **San José scale** (Aspidiotus perniciosus). A small circular scale with a central nipple. It is not readily seen unless very abundant. Infests many trees and shrubs. The specimens show variations in the appearance of the scales and how it may be disseminated by budding. The young appear from early June till cold weather. A very prolific and dangerous species.

Treatment: destroy badly infested trees, specially if young, and spray others thoroughly with 20% mechanical emulsion of crude petroleum just before the buds start in the spring. Kerosene emulsion or whale oil soap solution may be used in the same way, but neither has proved equally effective. The last two are recommended for summer treatment from the time the young appear, using 10% kerosene emulsion or whale oil soap at the rate of 1 pound to 4 gallons of water, and applying at intervals of about 10 days till the middle of September. Small trees can be fumigated with hydrocyanic acid gas with excellent results, using 1

pound of cyanide of potassium to 150 cubic feet of space and treating before the buds start in the spring.

17 **English oyster scale** (*Aspidiotus ostreaeformis*). This resembles the San José scale in appearance, but has the nipple a little to one side of the center, and like it infests fruit trees. It occurs in many localities in this state and should be guarded against as occasionally it is found in great numbers.

Treatment: spray infested trees with a 20% crude petroleum emulsion before the buds start or with kerosene emulsion or whale oil soap solution when the young appear in June. Fumigate with gas.

18 **Putnam's scale** (*Aspidiotus ancylus*). Resembles the two preceding species, but is less injurious. It attacks various trees. The young appear the latter part of June.

Treatment: same as preceding.

SMALL FRUIT AND VINE INSECTS

19 **Currant worm** (*Pteronus ribesii*). Greenish, black dotted saw fly larvae feeding on currant leaves in May, the common currant worm. The parent insect, a small, brownish, black-headed, four winged fly, appears the latter part of April, deposits eggs along the veins on the under side of the leaf. A second brood of flies occurs the last of May or in June.

FIG. 13 Immature currant worms (after Saunders)

Treatment: spray with hellebore or poison.

20 **Currant span worm** (*Diastictis ribearia*). Yellowish, black dotted span worms feeding on leaves in May and June. These are true caterpillars, and are easily distinguished from the preceding species by their "looping" habit when walking. The

parent insect is a delicate, yellowish moth with rather faint, dark markings.

FIG. 14 Currant span worms, larvae and pupa (after Saunders)

Treatment: spraying with poison, or handpicking.

21 **Currant stem-borers** (Sesia tipuliformis, Janus integer, Tenthredo rufopectus). The caterpillars boring in the woody stems are sesians. The maggots working in the tender tips may be either those of Janus or of Tenthredo. The parent of the stem-borer is a delicate, clear winged moth much resembling a hornet. The Janus is a black, four winged, slender fly, the female having the abdomen banded with red, the male with his abdomen all reddish. The Tenthredo is a heavier, black, four winged fly.

Treatment: burn stems infested with sesians and the wilting tips infested by the others.

22 **Raspberry gouty gall beetle** (Agrilus ruficollis). The irregular swellings on canes are produced by larvae of this pest. The parent insect is a small black beetle with a bronze colored collar. The grub is a slender, flat headed borer.

Treatment: cut and burn infested canes during winter or early spring.


FIG. 15 Raspberry gouty gall (after Riley)

23 **Light-loving grape vine beetle** (Anomala lucicola). Brownish or black beetles about $\frac{3}{8}$ inch long, resembling a small

June beetle. Occurs in immense numbers occasionally, and then it fairly riddles grape leaves.

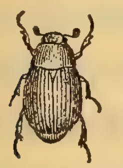


FIG. 16 Light-loving grape vine beetle (after Glover)

Treatment: dust vines with lime. Collect and destroy beetles.

24 **Spotted grape vine beetle** (P e l i d n o t a p u n c t a t a). A large, yellowish brown, black spotted beetle about 1 inch long, resembling a June beetle. Its size and beauty attract considerable attention, though the insect is rarely abundant enough to do much damage. The larva is one of the white grubs, and lives in decaying roots and stumps of various trees.

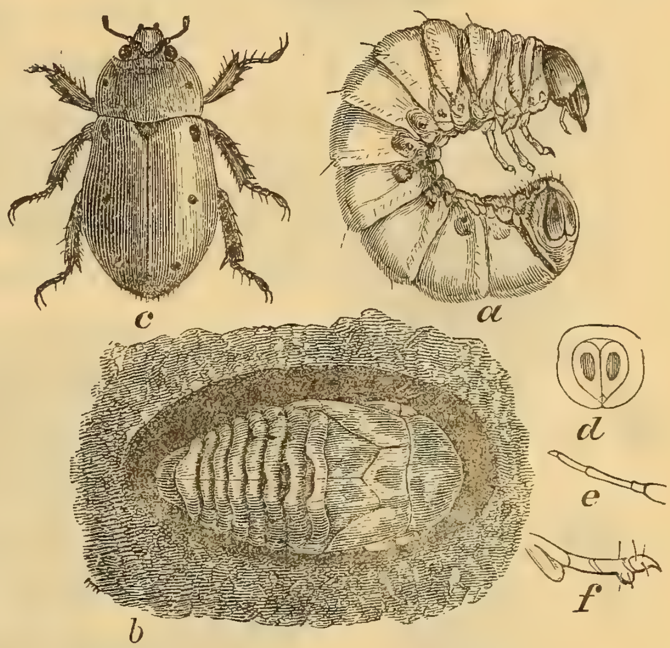


FIG. 17 Spotted grape vine beetle: *a* larvae; *b* pupa; *c* adult beetle; *d*, *e*, *f* minor parts strongly magnified (after Riley)

Treatment: handpicking.

25 **Grape vine flea beetle** (H a l t i c a c h a l y b e a). Greenish or blue jumping beetles about $\frac{1}{8}$ inch long, feeding on buds, or brownish, black dotted larvae about $\frac{1}{2}$ inch long, skeletonizing leaves. The beetles pass the winter in crevices of bark, appearing with warm weather, ready to attack the opening buds. This early feeding by the adults causes the most injury and should be vigilantly guarded against. The grubs begin their work about the latter part of May.

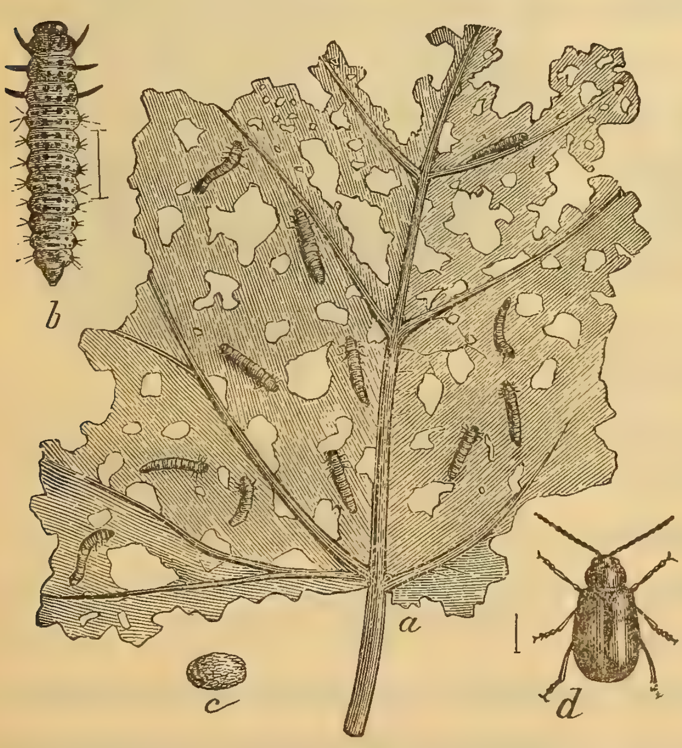


FIG. 18 Grape vine flea beetle: *a* grubs working; *b* grub magnified; *c* earthen cell of pupa; *d* adult beetle after Riley)

Treatment: the grubs are easily controlled by spraying with poison, and, if this be done, there will be fewer beetles to fight in the spring. Early injury by the beetles may also be prevented by spraying the buds thoroughly, using one pound of poison to 75 gallons of water, or by hand picking.

FIG. 19 Grape vine plume moth: *a* larvae; *b* pupa; *d* moth; *c* and *e* minor parts enlarged (after Riley)

26 Grape vine plume moth (Oxyptilus periscelidactylus). Small, greenish, hairy caterpillars webbing together terminal leaves. The caterpillars' work is most apparent the last of May or early June, and when abundant they may cause considerable injury. The delicate, brownish, plume moths appear about the middle of June.

Treatment: pick and destroy infested tips.

27 Eight spotted forester (Alypia octomaculata). Reddish, black-ringed caterpillars about 1½ inches long feeding on grape vine and Virginia creeper in spring. The parent insect is a beautiful black moth marked with eight yellow spots on the wings and with handsome orange tufts on the forward and middle pairs of legs.

Treatment: handpicking; spray with poison.

FIG. 20 Eight spotted forester: *a* caterpillar; *b* enlarged segment of the same; *c* female moth

28 White flower cricket (Oecanthus niveus). Series of punctures in twigs of of various kinds are made by this insect for the reception of its eggs. The injury is usually too little to call for remedial measures, specially as the insects are predaceous and beneficial, and should therefore be protected.

SHADE TREE PESTS

29 **White-marked tussock moth** (Notolophus leucostigma). Beautiful caterpillars having three black plumes, four yellow or white tufts, a coral red head, and body marked with black and yellow, defoliate horse chestnut, elm and other shade trees. The winter is passed in egg masses covered with a white, frothy substance, the caterpillars hatching the latter part

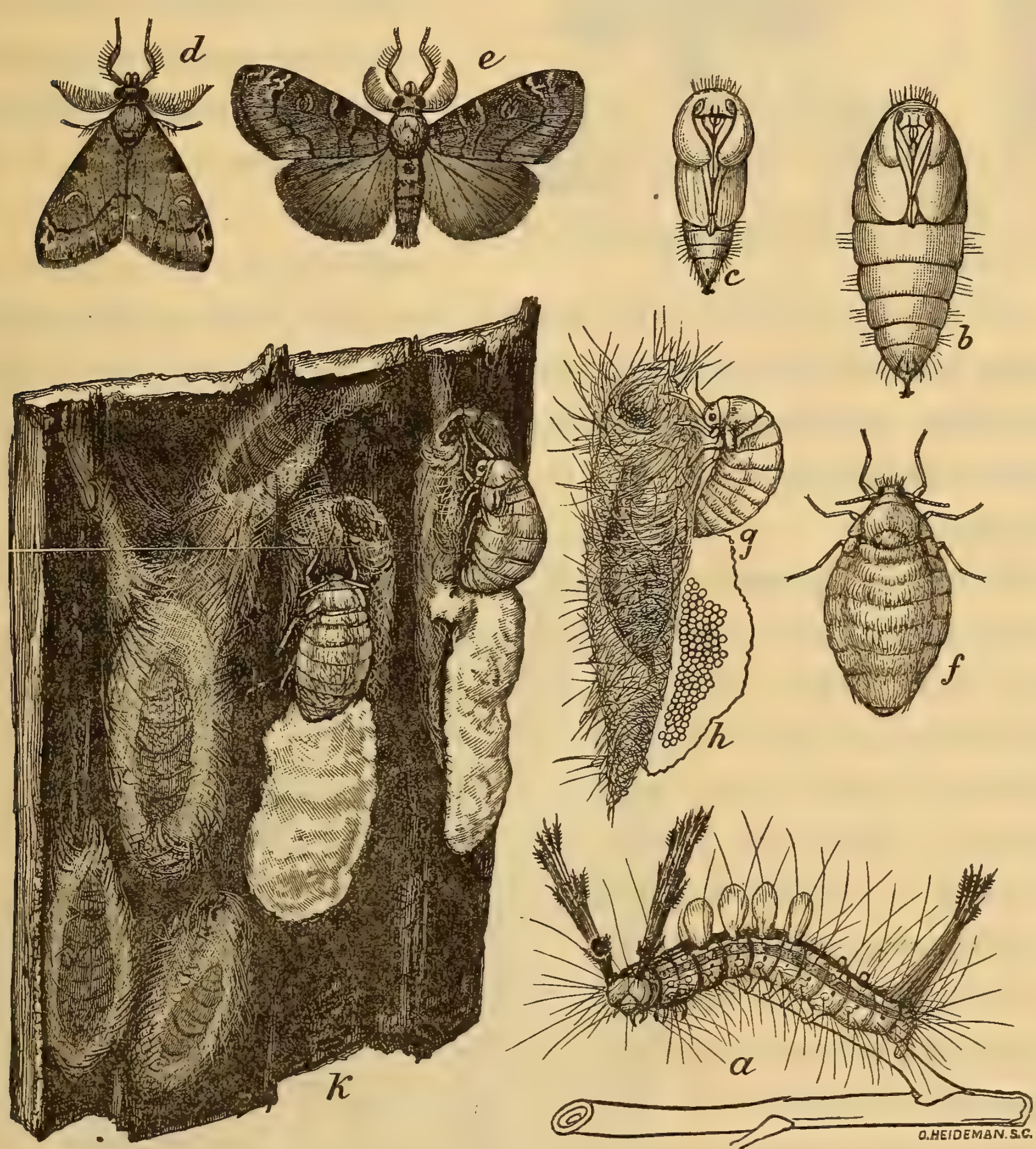


FIG. 21 White marked tussock moth: *a* larva; *b* female pupa; *c* male pupa; *d*, *e* male moth; *f* female moth; *g* same ovipositing; *h* egg mass; *i* male cocoons; *k* female cocoons, with moths laying eggs—all slightly enlarged (after Howard, U. S. dep't agr , Yearbook 1895)

of May and spinning up about a month later, the moths appearing in July. Two broods occur about New York city and but one farther north as a rule.

Treatment: remove and destroy the eggs or spray the foliage of the infested trees with poison.

30 **Forest tent-caterpillar: maple worm** (Clisiocampa disstria). Foliage of maple and fruit trees eaten in May and June by hairy blue headed caterpillars with silvery dots along the back. The cocoons are spun in June, the brown moth, with darker oblique bands across the wings, flying in July. Eggs in belts incircling smaller twigs are covered with a light brown protective substance, and remain unhatched till spring.

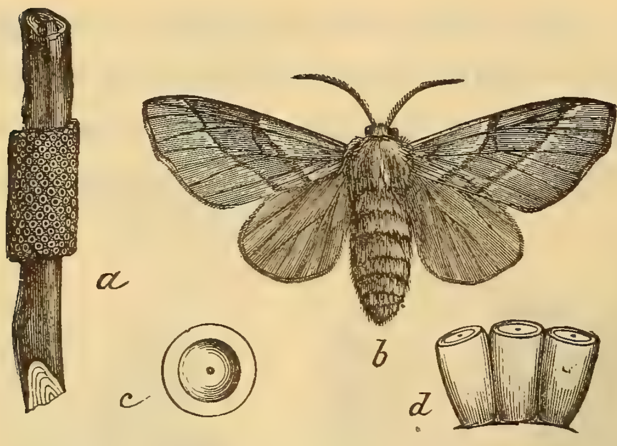


FIG. 22 Forest tent-caterpillar: *a* cluster of eggs; *b* female; *c* top view of an egg; *d* side view of several eggs (after Riley)

Treatment: remove and destroy the eggs; kill the caterpillars when massed on trunk and limbs, either by crushing or by spraying them with kerosene emulsion or with whale oil soap solution; spray the foliage of infested trees with poison; collect and destroy the cocoons.

31 **Pigeon Tremex** (Tremex columba). The large, four winged, brownish adults marked with yellow, frequently known as "horn tails", are usually found in July around diseased and dying tree trunks. The eggs are deposited a short distance within the bark, and the young borers occur near the surface, but full grown ones may make their way to the center of even large trees. This insect is not usually very injurious.

Treatment: cut and burn badly infested trees.

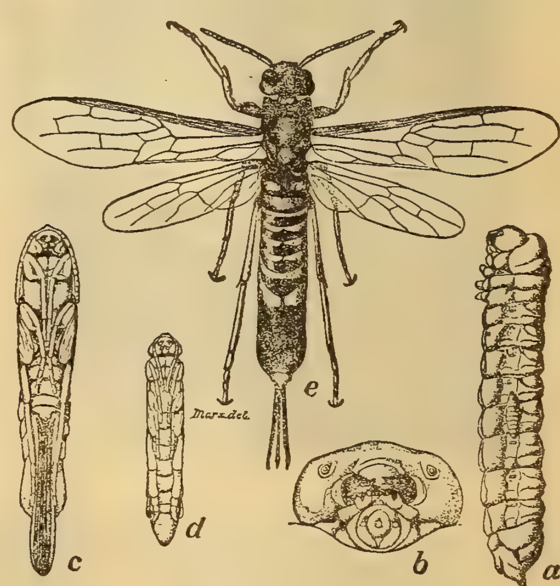


FIG. 23 Pigeon Tremex: *a* larva showing the Thalessa larva fastened to its side; *b* head of larva; *c* female pupa; *d* male pupa; *e* adult female (reduced after Marx)

32 **Lunate long sting** (Thalessa lunator). A magnificent brownish, wasp-like insect, with yellow markings and a

slender ovipositor or "tail" 2 to 4 inches long. It frequents elms and maples infested by the pigeon Tremex, and occasionally is found with the ovipositor stuck in the wood. The characteristic attitude of this parasite when forcing its long ovipositor into the wood is well shown in the accompanying figure. The white legless grubs attach themselves to the borers and suck their life out. *This insect should* therefore *be protected.*

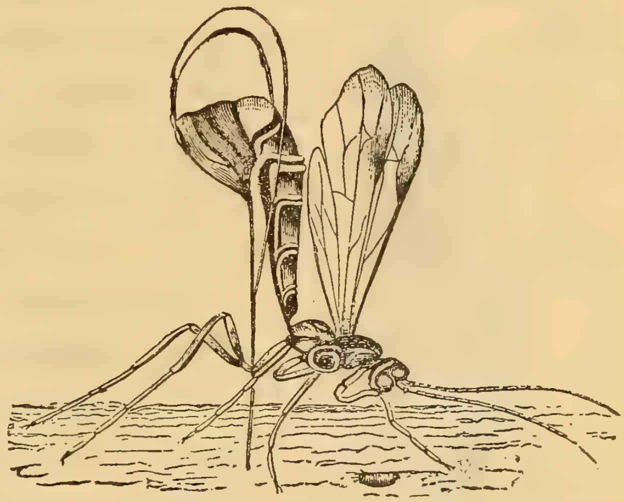


FIG. 24 Lunate long sting ovipositing

33 **Cottony maple tree scale insect** (Pulvinaria innumerabilis). The under side of smaller limbs of soft maple are sometimes festooned with this cottony insect, though more frequently it occurs in small masses. The young appear in July. Sometimes this insect is very injurious on Long Island and occasionally is abundant in other sections of the state.

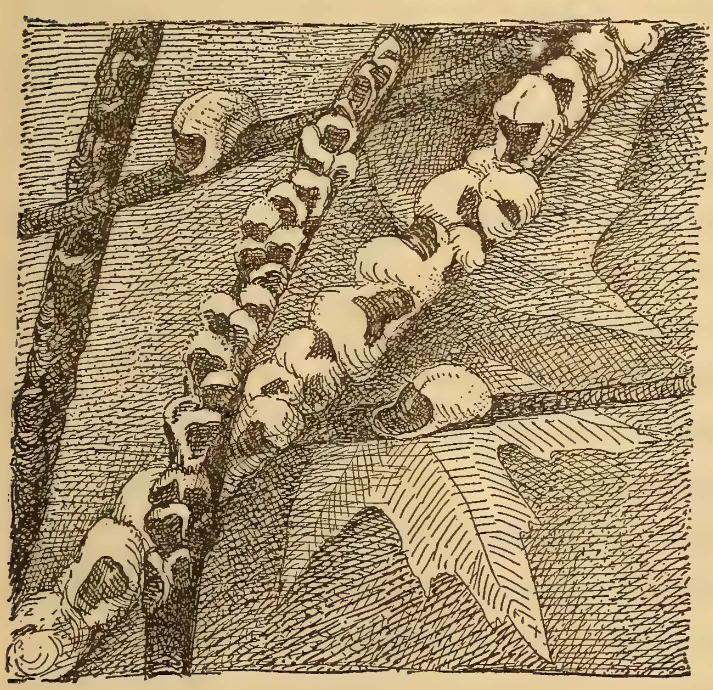


FIG. 25 Cottony maple tree scale insect. Adult females on twigs with eggs sacs—natural size (after Howard; U. S. dep't agr., div. ent. bull. 22, n. s.)

Treatment: spray young with kerosene emulsion or whale oil soap solution. Brush or scrape off and destroy the old scales.

34 **Sugar maple borer** (Plagionotus speciosus). Diseased or loose bark and exposed dead wood indicate the work of

this pest. The white, legless, fleshy grubs of this beetle frequently cause serious injury by running transverse burrows just beneath the bark. The stout, black beetles, about 1 inch long, with bright yellow markings, occur from June to August. They deposit eggs in the bark, and these places become more apparent later through sap flowing from the living tissues gnawed by the grub and producing a discoloration around the wound.

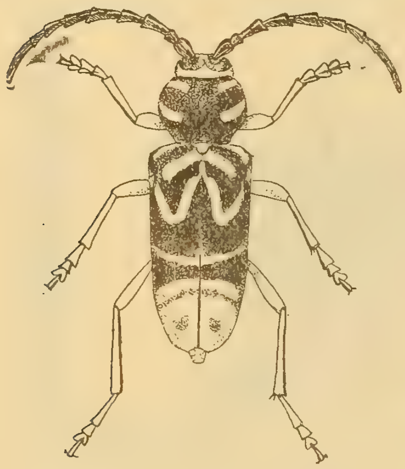


FIG. 26 Sugar maple borer, parent beetle (original)

Treatment: burn badly infested trees. Search for places where eggs have been deposited and dig out the young borers in the fall. Protect trees with carbolic soap wash from June to August.

35 **Maple tree pruner** (Elaphidion villosum). Small limbs of maple, oak and other trees nearly eaten off by an insect and dropping in September, usually contain the burrows of this species. The parent of the borer is a nearly cylindric, brown beetle which usually remains within the fallen twig till the next June.

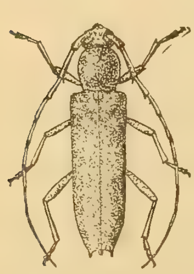


FIG. 28 Maple tree pruner (original)

Treatment: collect infested limbs on the ground and burn before spring.

FIG. 27 Injury produced by a transverse burrow of borer in a sugar maple about 18 inches in diameter

36 **Elm leaf beetle** (Galerucella luteola). Irregular round holes are eaten in young foliage, followed by the grubs gnawing the under portions of the leaves, which then dry and

turn brown. The yellowish, black striped beetles, about $\frac{1}{4}$ inch long, appear in early spring and lay eggs in May. The grubs feed in June, changing to yellow pupae the latter part of the month. A second brood occurs in July and extends into September. Known to occur in this state on Long Island, in the Hudson river valley north to Schuylerville, and in a few places in western central New York. This pest prefers European elms, but when numerous will seriously injure American elms.

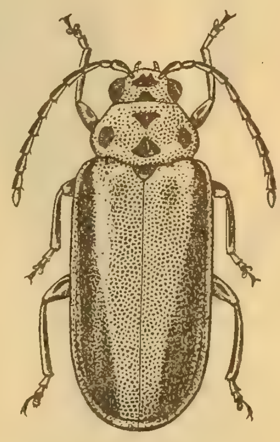


FIG. 29 Elm leaf beetle, adult (reduced from Howard, U. S. dep't agr., Yearbook 1895)

Treatment: spray the young foliage of infested trees with poison early in May to kill the beetles. The spray *must be thrown* on the *under surface* of the leaf in order to kill the grubs. Kill larvae and pupae on and near trunks of the trees either with hot water, with kerosene emulsion or by sweeping up and burning.

37 **Spiny elm caterpillar** (Euvanessa antiopa). Large black, red marked, spiny caterpillars about 2 inches long may frequently be seen in June feeding on the leaves of elm, willow and several other trees. The parent butterfly is a handsome purplish insect with yellow bordered wings. There are two annual generations in New York state.

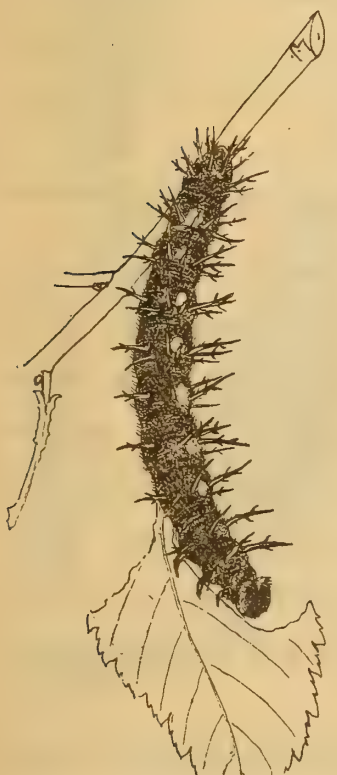


FIG. 30 Spiny elm caterpillar (original)

Treatment: remove the gregarious caterpillars and crush them or spray the infested limbs with poison.

38 **Elm bark louse** (Gossyparia ulmi). The adult females in June appear like clusters of small lichens on the under side of the smaller limbs of European elms. The young emerge in July. This insect appears to be generally distributed in the Hudson river valley, and will probably soon make its way to

other parts of the state. The draft on a badly infested tree in June is very great; the excretions of the bark lice falling in fine showers keep stones beneath wet even on good drying days. The leaves of infested trees are frequently covered with a blackening fungus, which grows in this secretion.

FIG. 31 Elm bark lice on twig, full grown females (original)

Treatment: spray the young with kerosene emulsion or whale oil soap solution.

39 **Elm borer** (*Saperda tridentata*). Diseased or dead bark is usually the first indication of injury by this insect. The tree soon becomes unthrifty and examination of the bark may show in its inner portions white, flattened, legless grubs, which frequently cause considerable injury. The beetles appear from early May till latter part of June.

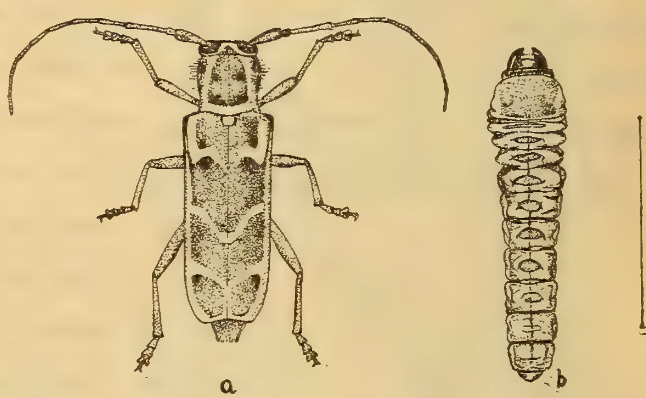


FIG. 32 Elm borer: *a* adult; *b* half grown larva—hair line represents natural size of latter (original)

Treatment: cut and burn badly infested trees. Protect valuable trees with carbolic soap wash during May and June.

40 **Elm snout beetle** (*Magdalis barbita*). Thick, fleshy, legless grubs working in inner bark of elm. Follows attack by the elm-borer and occasionally is very abundant. The parent insect is a black snout beetle about $\frac{1}{4}$ inch long. It sometimes occurs in large numbers and may have associated with it the reddish, closely allied *Magdalis armicollis*.

FIG. 33 Elm snout beetle, *Magdalis barbita* (original)

Treatment: burn badly infested trees and keep others vigorous.

41 **Fall web worm** (H y p h a n t r i a c u n e a). Web tents in July and August inclosing leaves on the tips of branches, the eaten foliage turning brown. This insect attacks many trees and occasionally is very destructive. The parent insect is a whitish moth.

Treatment: destroy webs and their inhabitants or spray foliage of affected limbs with poison.

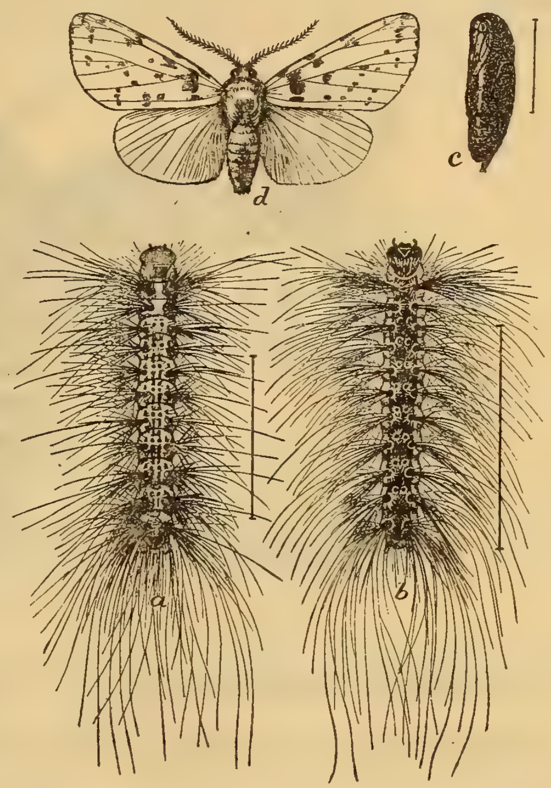


FIG. 34 Fall web worm: *a* light form of full grown larva; *b* dark form of same; *c* pupa; *d* spotted form of moth (reduced from Howard, U. S. dep't agr., Yearbook 1895)

42 **Bag worm** (T h y r i d o p t e r y x e p h e m e r a e f o r m i s). Defoliated evergreens and other trees are found infested in late summer and fall with curious caterpillar containing bags of this insect. Occurs in vicinity of New York city and is sometimes very destructive, specially to evergreens. The female is wingless and never leaves the bag.

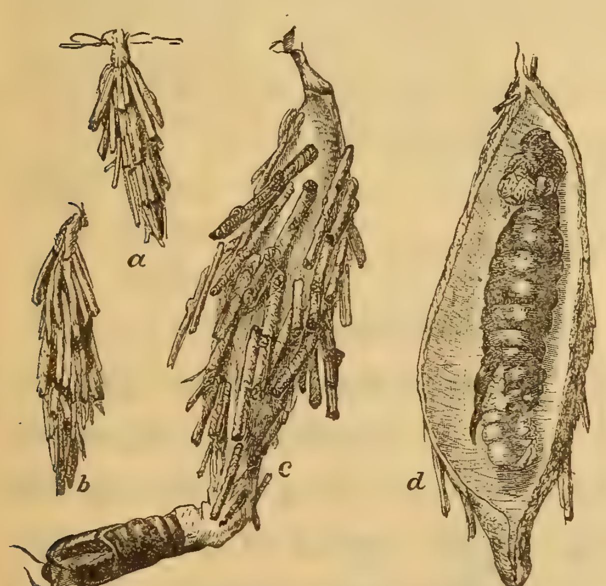


FIG 35 Bag worm: *a*, *b*, *c* at successive stages of growth; *c* male bag; *d* female bag (reduced from Howard, U. S. dep't agr., Yearbook 1895)

Treatment: collect and destroy bag worms or spray with poison.

43 **Leopard moth** (Z e u z e r a p y r i n a). The whitish, black spotted caterpillar of this imported pest makes large burrows in trunks and limbs. It attacks most kinds of trees and shrubs grown about New York city, and has already made its way about 40 miles north. The parent insect is a white, black or blue spotted moth with a wing spread of about 2 inches.

Treatment: dig out young borers. Kill others by injecting carbon bisulfid in the burrow and then stopping the orifice with putty or soap. Burn badly infested trees.

FIG. 36 Leopard moth, adult female (after Pike)

44 **Bronze birch-borer** (Agrilus anxius). If infested bark is examined, a slender flat-headed grub may be found running burrows in all directions in the inner portions. White and other birches are attacked, one of the first indications of attack being the dying of the tree at the top. It is very injurious at present in Buffalo. The beetles appear in June.

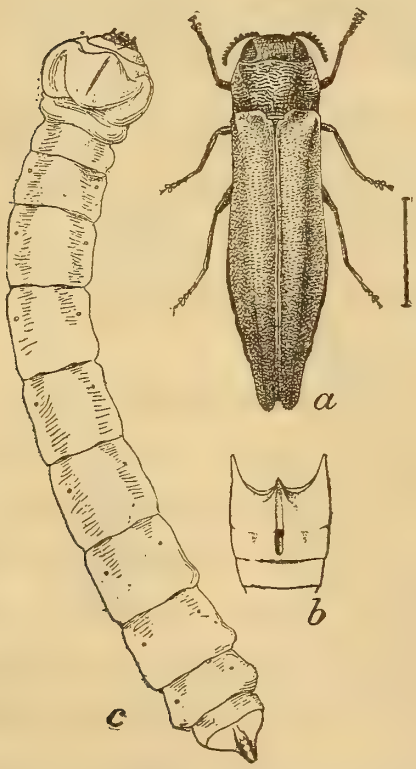


FIG. 37 Bronze birch borer: *a* female beetle; *b* first abdominal segments of male from below; *c* larva from above—all enlarged about 3½ times (after Chittenden, U. S. dep't agr., div. ent., bull. 18, n. s.)

Treatment: cut and burn badly infested trees.

GARDEN INSECTS

45 **Colorado potato beetle** (Doryphora 10-lineata). Stout yellowish beetles with black striped wing covers appear in early spring, feed, and deposit yellowish eggs in clusters on under surface of leaves. The reddish, black marked grubs also devour the foliage.

Treatment: spray vines with poison; handpicking.

46 **Squash vine-borer** (Melittia satyriniformis). Wilting of one or more runners is caused by a whitish caterpillar boring in the stem near the root. The parent insect is a beautiful, clear winged moth with brownish black fore wings, transparent

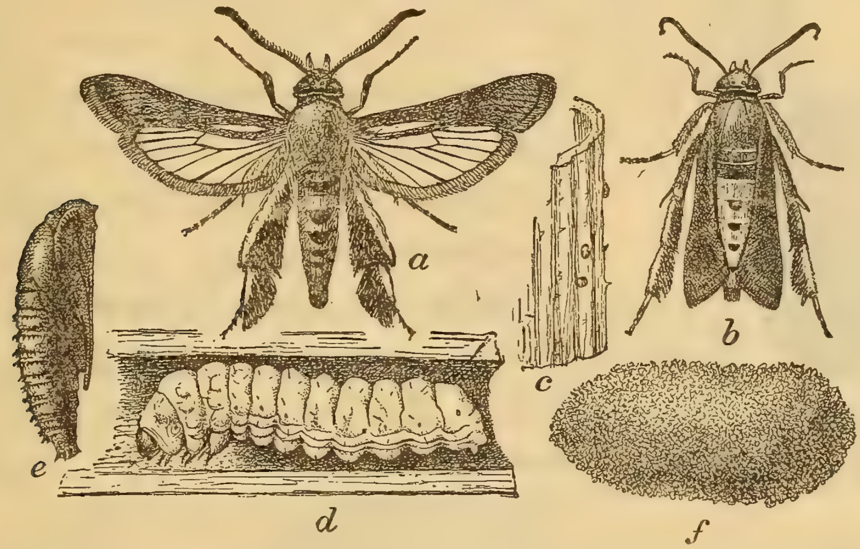


FIG. 38 Squash vine borer: *a* male moth; *b* female moth with wings folded as at rest; *c* eggs on bit of squash stem; *d* full grown larva in vine; *e* pupa; *f* pupal cell—all enlarged ⅓ (after Chittenden, U. S. dep't agr., div. ent., circ. 38, 2d ser.)

hind wings and with legs beautifully ornamented with black and orange tufts. She deposits eggs on almost any part of the plant.

Treatment: plant a few early squashes as a trap crop, destroying these vines as soon as the crop is secured. Slit the softer, infested portions, remove the borers and cover the wounded part with earth. Protect young plants with netting.

47 **Striped cucumber beetle** (Diabrotica vittata). Yellow beetles about $\frac{1}{4}$ inch long, striped with black, occur in numbers on cucumber and squash vines. The slender, whitish, brown headed grubs live on the roots of these plants and frequently cause great injury.

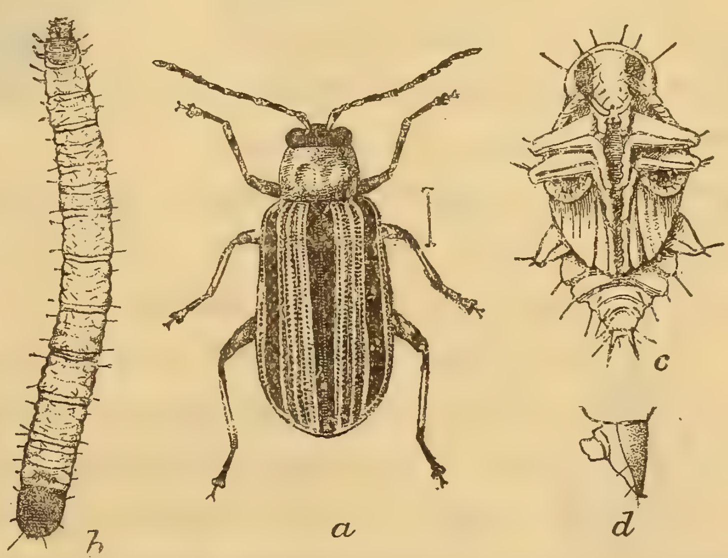


FIG. 39 Striped cucumber beetle: *a* beetle; *b* larva; *c* pupa; *d* side view of anal segment (after Chittenden, U. S. dep't agr., div. ent., circ. 31, 2d ser.)

Treatment: protect young vines with netting. Dust vines with ashes, plaster of paris, etc. Poison trap crop of squash. Clean culture and the destruction of vines as soon as the crop is harvested will do much to keep this pest in check.

48 **Cucumber flea beetle** (E p i t r i x c u c u m e r i s). Brownish, gnawed spots on leaves made by numerous black jumping beetles about $\frac{1}{16}$ inch long. They are frequently very injurious. The young live on the roots of various plants.

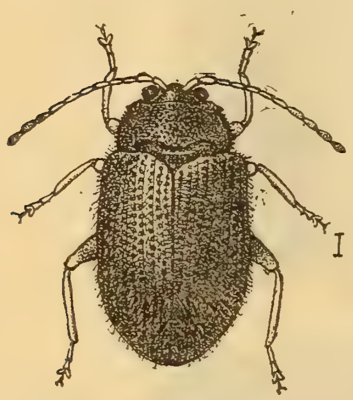


FIG. 40 Cucumber flea beetle, much enlarged (after Chittenden, U. S. dep't agr., div. ent., bull. 19, n. s.)

Treatment: spray vines with bordeaux mixture, with poison or with a combination of the two. Dusting the affected plants with plaster of paris, ashes, etc. will also afford some protection.

49 **Squash bug** (A n a s a t r i s t i s). Wilting leaves with their under surface infested by greenish young or by the large, grayish brown stink bugs about $\frac{3}{4}$ inch long. The eggs are deposited in clusters on the under surface of the leaves.

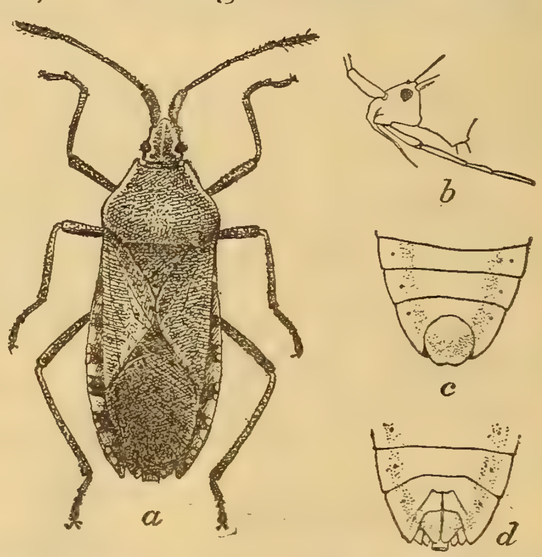


FIG. 41 Squash bug: *a* adult female twice natural size; *b*, *c* and *d* details of structure more enlarged (after Chittenden, U. S. dep't agr., div. ent., bull. 19, n. s.)

Treatment: collect and destroy the early appearing bugs. Place chips and similar shelters near the vines and kill each morning the bugs collected underneath. Crush the brownish eggs on under surface of the leaves.

50 **Common asparagus beetle** (C r i o c e r i s a s p a r a g i). Slate colored grubs about $\frac{1}{3}$ inch long or beetles about $\frac{1}{4}$ inch long, prettily marked with yellow, blue and red, eat the more tender parts of the plants. They breed during the greater part of the growing season. Occurs on Long Island, in the Hudson river valley and in the lake regions of the western part of the state.

Treatment: the daily cutting of producing beds serves to keep

the pest under control then. Young beds and others badly infested after cutting ceases should be sprayed with poison, or a mixture of paris green with plaster or flour should be dusted on the plants while they are wet with dew.

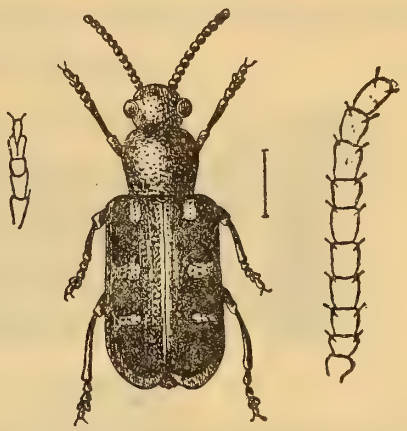


FIG. 42 Asparagus beetle, enlarged about six diameters, with farther enlargement of antenna and front tarsus

51 **12 spotted asparagus beetle** (Crioceris 12-punctata). Slate colored grubs about $\frac{1}{3}$ inch long or stout, nearly cylindric red beetles about $\frac{1}{4}$ inch long, with 12 black spots, eating the more tender portions of the plant. Known to occur in the state in several places in the Hudson river valley and in a number of widely separated localities in the western part of the state.

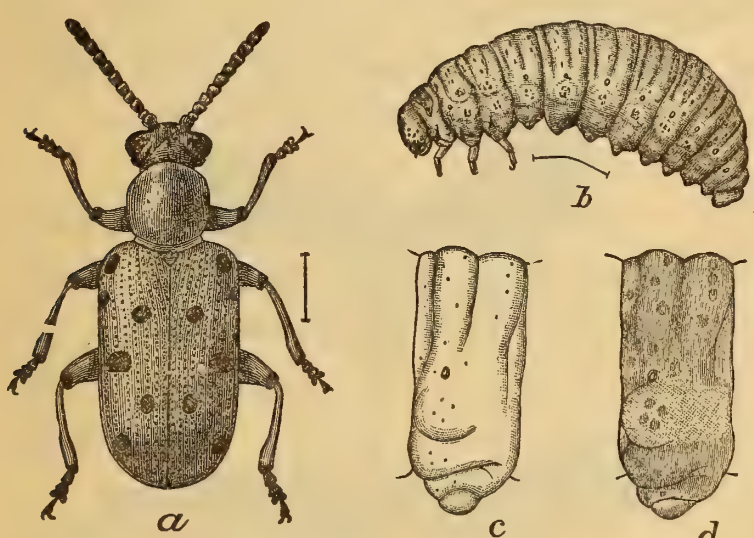


FIG. 43 12 spotted asparagus beetle: *a* adult beetle; *b* larva; *c*, *d* enlarged segments (after Chittenden, U. S. dep't agr., Yearbook 1896)

Treatment: same as the preceding.

52 **Red headed flea beetle** (Systena frontalis). Ragged holes and brown spots made by small, jumping, black, red headed beetles about $\frac{3}{16}$ inch long. Sometimes occurs in large numbers.

Treatment: spray affected plants with poison or with poisoned bordeaux mixture, preferably the latter. Clean culture will do much to prevent attack by this insect.

FIG. 44 Red headed flea beetle: *a* showing leg adapted to jumping—much enlarged, *b* adult beetle, enlarged (original)

53 **Blister beetles** (Epicauta cinerea, E. vittata). Feeding in July and August on the foliage of potato and other plants, cylindric, soft beetles about $\frac{5}{8}$ inch long and black and gray, or black striped with yellow.

Treatment: as the grubs of these beetles are known to feed on the eggs of grasshoppers and are therefore beneficial, the adults should be destroyed, by spraying affected plants with poison or by beating the insects into pans containing water and kerosene, only when necessary.

FIG. 45 Margined blister beetle, Epicauta cinerea

FIG. 46 Striped blister beetle, Epicauta vittata

54 **Bumble flower beetle** (Euphoria inda). Brownish mottled beetles about $\frac{5}{8}$ inch long feeding in ears of green corn, attacking peaches, etc. The young are white grubs, and may be found in partially decayed vegetable matter, and the beetles may frequently be seen in the spring flying and making a humming much like a bumblebee. This insect is not usually very destructive.

FIG. 47 Bumble flower beetle, natural size: *a*, *b*, *c* enlargements of antenna, anterior leg and posterior leg

Treatment: handpicking.

55 **Wireworms** (Elateridae). Cylindric, hard, yellowish brown grubs attacking various plants, frequently injuring planted seeds. The parent insects are the brown snapping beetles so commonly seen.

Treatment: fall plowing. Trapping beetles with poisoned baits.

56 **Stalk borer** (Hydroecia nitela). Wilting potato vines may be caused by a brown, white striped active caterpillar, about 1 inch long boring within the stems. The parent is a brownish moth with a conspicuous yellow line near the outer third of the fore wings. This insect attacks many thick stalked, herbaceous plants, and is a difficult one to control.

FIG. 48 Stalk borer, moth and caterpillar (after Riley)

Treatment: burn the infested stalks before September.

57 **Variegated cut worm** (Peridroma saucia). This is a stout, brownish cut worm about 1½ inches long, with obscure markings. It is very injurious to various garden plants. Its operations on carnations in a greenhouse are shown. The adult is an obscurely colored brownish moth.

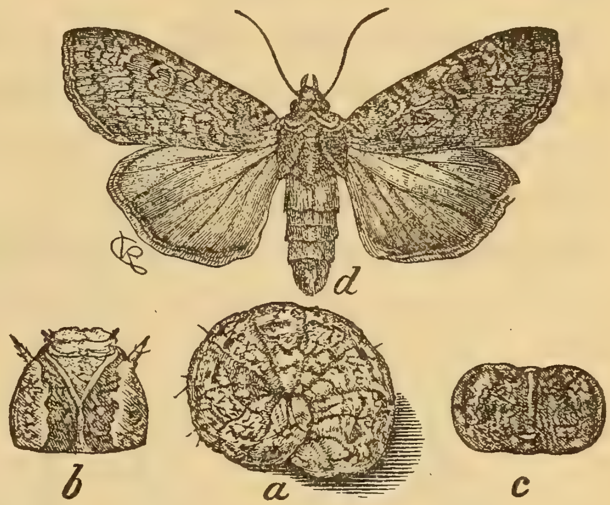


FIG. 49 Variegated cut worm: *a* larva; *b* and *c* segments of the same enlarged; *d* moth (after Riley)

Treatment: place poisoned baits near plants to be protected.

58 **Zebra caterpillar** (Mamestra picta). Brilliantly marked black and yellow, red headed caterpillars about 2 inches long are frequently found on cabbage, beets and other garden crops. These handsome caterpillars are general feeders, and occasionally are found in very large numbers. The moth is marked with deep shades of brown. There are two broods annually.

FIG. 50 *a* zebra caterpillar; *b* its moth (after Riley)

Treatment: spray affected plants with poison, hellebore or pyrethrum water.

59 **Cabbage butterfly** (Pieris rapae). The large irregular holes eaten in cabbage by a greenish caterpillar are usually the work of this insect. The white butterflies are frequently very abundant in the field. A common and widely distributed pest.

FIG. 51 Cabbage butterfly, female (after Riley)

Treatment: capture the butterflies with nets. Spray young cabbage with poison, older ones with hellebore or pyrethrum water. Dust with lime.

60 **Cabbage thrips** (T h r i p s t a b a c i). Cabbage and lettuce frequently show white spots as though blasted, caused by minute yellowish or brown insects. These little creatures are scarcely visible to the unaided eye.

Treatment: spray affected plants at the beginning of the trouble with kerosene emulsion or a soap solution.

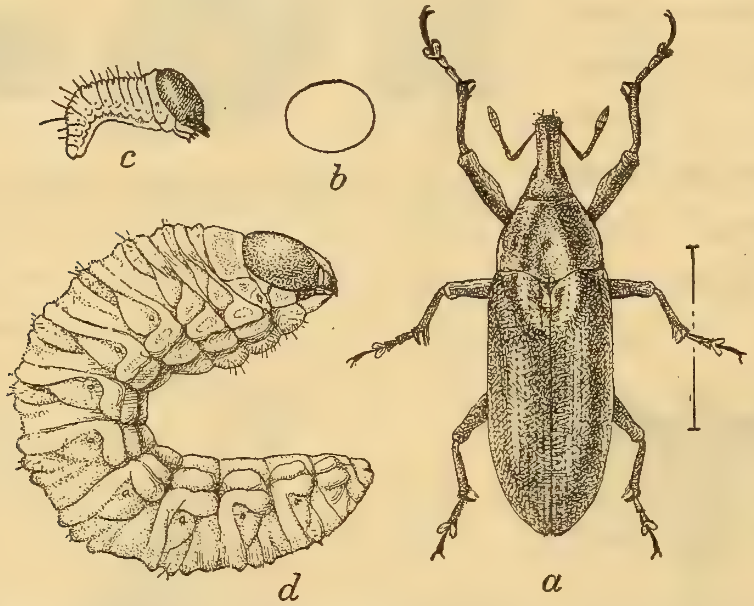


FIG. 52 Rhubarb curculio: *a* adult beetle; *c* newly hatched larva; *d* full-grow larva; *e* pupa—all about twice natural size (after Chittenden, U. S. dep't agr., div. ent., bull. 23, n. s.)

61 **Rhubarb curculio** (L i x u s c o n c a v u s). Wilting rhubarb leaves and punctures in the leaf stems are usually caused by a nearly cylindric, black, extremely "hard shelled" beetle with more or less of a golden bloom on it. The grubs burrow in the stems and leaf stalks of dock as well as of rhubarb.

Treatment: the beetles can be collected and destroyed by hand whenever injurious. They are abroad in June.

62 **Tarnished plant bug** (L y g u s p r a t e n s i s). Small yellowish and black bugs about $\frac{1}{4}$ inch long, frequenting many plants and injuring most garden crops and some trees. A most serious injury by this pest is the extensive blasting of peach buds on nursery stock.

FIG. 53 Tarnished plant bug (after Riley)

Treatment: handpicking or dusting with ashes. Burn all rubbish in the fall.

63 **Four lined leaf bug** (Poecilocapsus lineatus). Bugs about $\frac{5}{16}$ inch long, yellowish, with four black stripes, frequent various plants and injure some considerably. A serious enemy of the currant. There is but one brood annually. The winter is passed in the egg, which hatches about the last of May, the insect being full-grown about the middle of June. The white eggs are deposited in slits made in the wood.

Treatment: dust affected plants with ashes. Spray young with kerosene emulsion. Cut and burn tips of bushes containing eggs.

GRASS INSECTS

64 **Army worm** (Leucania unipuncta). Brownish, white striped caterpillars about 2 inches long devouring grasses and allied plants occasionally appear in immense numbers. There are two or three generations annually in this state, but it is very exceptional that this pest is as destructive as it was in 1896. The parent moth is brownish, with a small white spot on the fore wing. The eggs are laid by preference in tough stalks of rank herbage, such as grows along neglected ditches, etc.

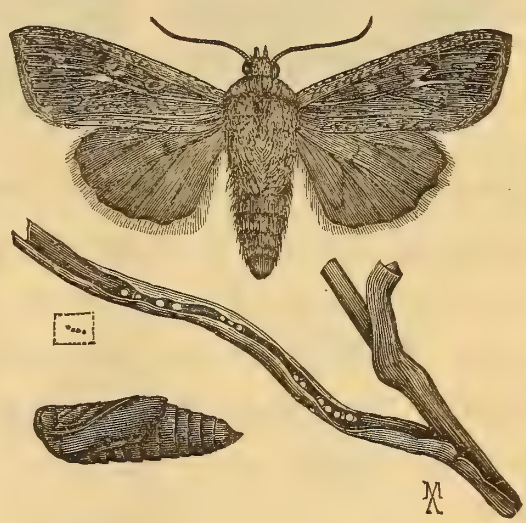


FIG. 54 Army worm: moth, pupa and eggs in natural position in a grass leaf—all natural size (after Comstock)

Treatment: exclude the pests by ditching, or kill with poisoned baits. Prevent their occurrence by clean culture.

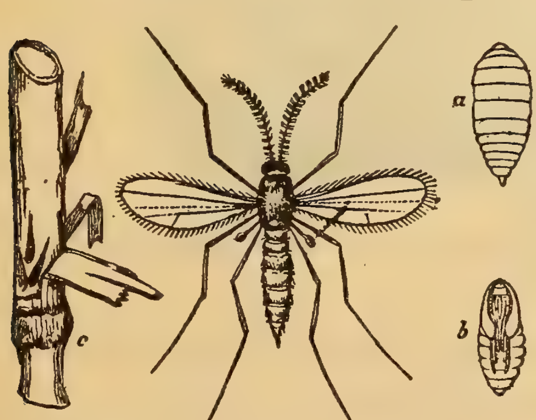


FIG. 55 Hessian fly

65 **Hessian fly** (Cecidomyia destructor). Darker, broad leaves with free stooling, followed by the infested patches turning yellow, are the usual indications of attack. There are two broods annually,

the adults of one appearing in September, those of the other in April or May, the latter being the cause of the lodged grain.

Treatment: late planting in connection with earlier sown decoy strips to be plowed under in late fall. Cut straw high in infested fields and burn the stubble. Clean culture and rotation of crops.

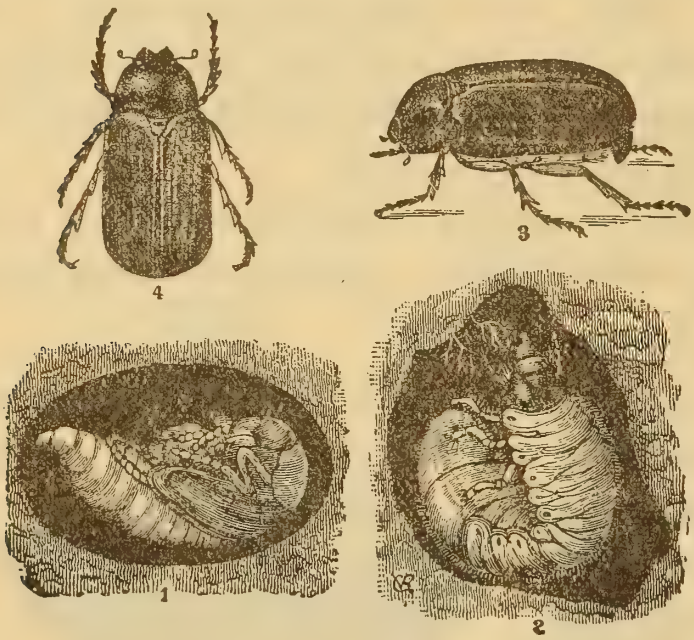


FIG. 56 Lachnosterna fusca: 1 pupa; 2 the white grub in its ground cell; 3 and 4 adult May beetle (after Riley)

66 **White grubs** (Lachnosterna fusca, Allorhina nitida). Fleshy, white, brown headed grubs severing grass roots and those of other plants. These pests frequently occur in such numbers as to kill large patches of grass. The parent insects are large brownish beetles or greenish, marked with yellow, in the case of Allorhina, which latter occurs in vicinity of New York city. The grub of Allorhina has the peculiar habit of turning on its back and progressing by a peculiar undulating motion whenever it travels.

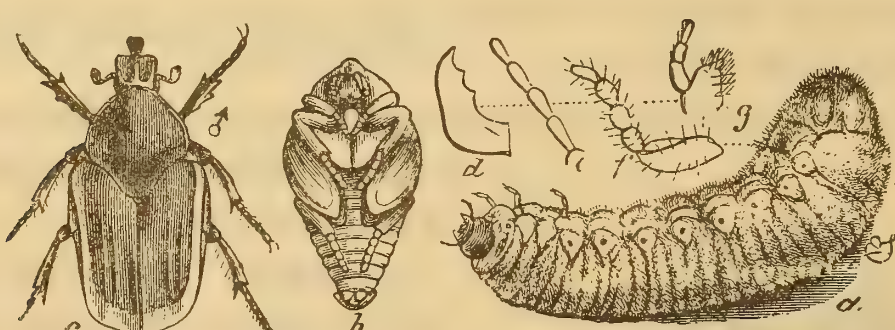


FIG. 57 Allorhina nitida: *a* larva; *b* pupa; *c* male beetle; *d, e, f, g* minor parts of larva magnified (after Riley)

Treatment: spray badly infested areas liberally with kerosene emulsion just before a rain. Dig and destroy the grubs.

67 **Grasshoppers.** A number of species attack various crops. Occasionally they occur in very large numbers. The eggs are deposited in the ground, and are fed on by the young of certain blister beetles.

Treatment: place poisoned baits near crops to be protected.

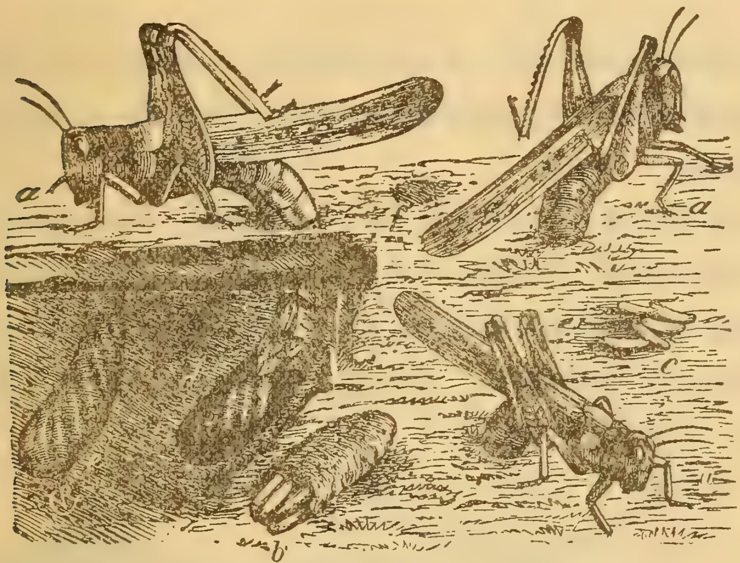


FIG. 58 Rocky mountain locust: *a*, *a*, *a* female in different positions ovipositing; *b* egg-pod extracted from the ground, with the end broken open; *c* some separate eggs; *d*, *e* a section showing an egg-pod placed and another being placed; *f* where a pod has been covered up (after Riley)

FIG. 59 Red-legged locust

HOUSEHOLD INSECTS

68 **House fly** (*Musca domestica*). Easily recognized as the more common fly around houses. It breeds in manure and

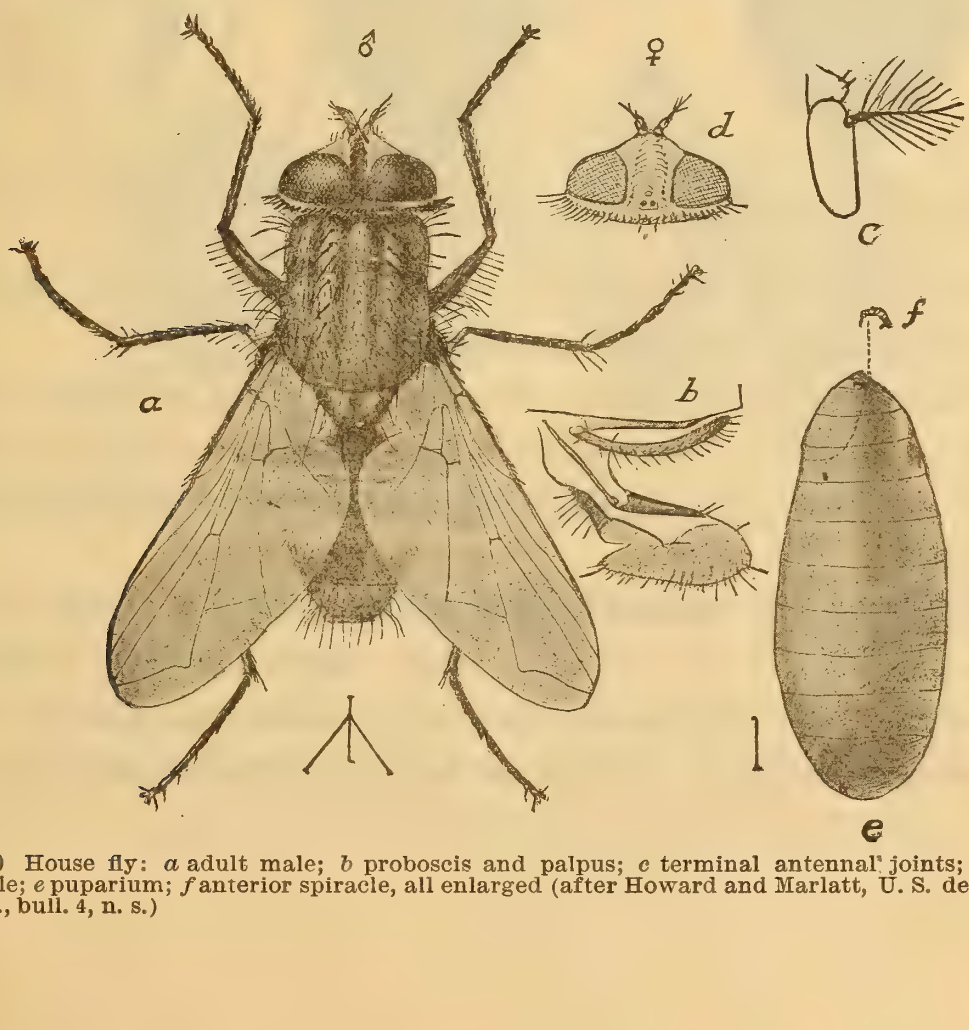


FIG. 60 House fly: *a* adult male; *b* proboscis and palpus; *c* terminal antennal joints; *d* head of female; *e* puparium; *f* anterior spiracle, all enlarged (after Howard and Marlatt, U. S. dep't agr., div. ent., bull. 4, n. s.)

dooryard filth. One fly may deposit as many as 120 eggs, and under favorable conditions but 10 days are required to complete the life cycle.

Treatment: exclude with screens. As it breeds in manure and garbage, keeping this material cleaned up or inaccessible to flies will reduce their numbers.

69 **Bed bug** (Acanthia lectularia). A flattened, reddish, wingless insect about ¼ inch long frequenting houses, specially those affording numerous cracks where it can find shelter and where uncleanliness prevails. This disgusting intruder

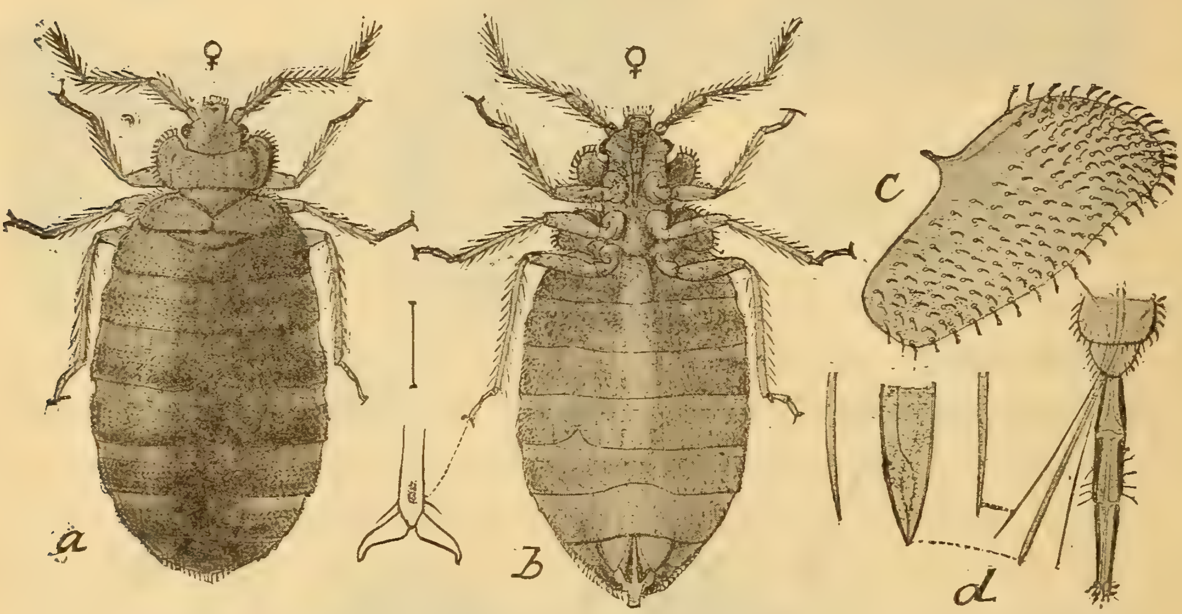


FIG. 61 Bed bug: *a* and *b* adult females gorged with blood, upper and under surfaces *c*, *d*, structural details (after Marlatt, U. S dep't agr., div. ent., bull. 4, n. s.)

requires about seven weeks to complete its life cycle. It is able to exist for long periods without food.

Treatment: apply benzin, kerosene, or other petroleum oil to crevices in infested beds. Corrosive sublimate may be used in same manner. Fumigation with sulfur is valuable wherever possible.

70 **Kissing bug: masked bed bug hunter** (Opsicoetus personatus). A brownish or black insect about ¾ inch long. It is attracted by lights, and its young, which conceals itself by a covering of lint, etc. is said to have a partiality for bed bugs.

Not usually harmful, though it can inflict a severe bite or "sting." It is frequently found in or about houses.

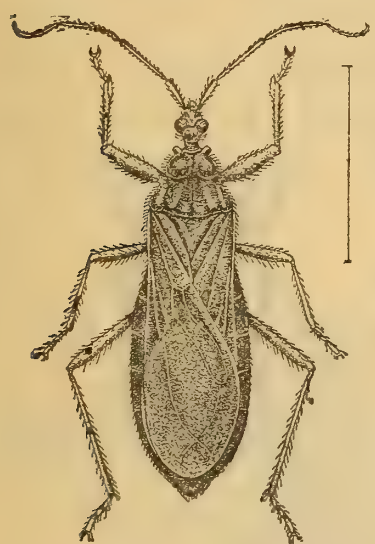


FIG. 62 Kissing bug: masked bed bug hunter, about twice natural size (after Howard, U. S. dep't agr., div. ent., bull. 22, n s.)

Treatment: screens should exclude it most effectually.

71 **Buffalo carpet beetle** (Anthrenus scrophulariae). The larvae are easily recognized by their shaggy appearance, being provided with coarse bristles along the sides and at the posterior extremity of the body. The beetles are about $\frac{1}{8}$ inch long, black, marked with white and down the middle of the back with a red line which widens into three projections. These pretty beetles are very common on flowers, specially spiraeas and tulips, and are frequently brought into houses with the blossoms.

Treatment: use rugs or matting in place of carpet whenever possible. Infested carpets should be taken up and sprayed with benzin, and the cracks in the floor should be filled with plaster of paris before relaying.

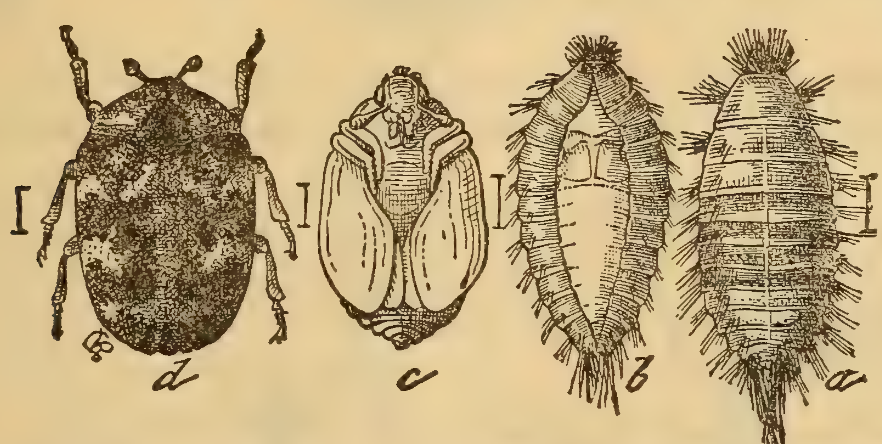


FIG. 63 Buffalo carpet beetle: *a* larva; *b* cast skin of larva at molting; *c* pupa; *d* beetle—enlarged from natural sizes shown in accompanying lines (after Riley)

72 **Black carpet beetle** (Attagenus piceus). The light brown cylindric larva has a long "tail" of slender hairs. The adult is a small oval black beetle nearly $\frac{3}{16}$ inch long. This

species has a decided taste for feathers, though it infests carpets and attacks many other substances. It is quite common in Albany.

Treatment: same as for the preceding.

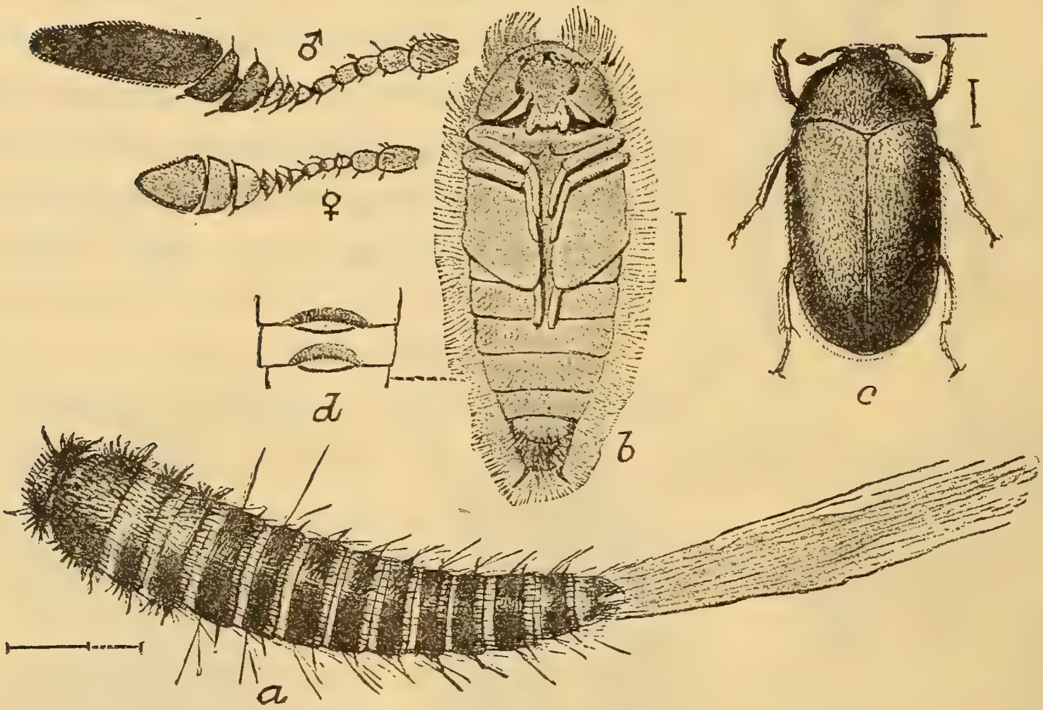
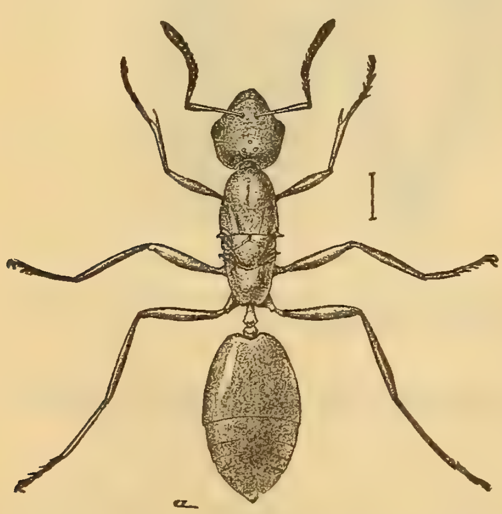


FIG. 64 Black carpet beetle: *a* larva; *b* pupa; *c* adult beetle—all enlarged (after Howard, U. S. dep't agr., div. ent., bull. 4, n. s.)

73 Little red ant (Monomorium pharaonis). This is the common yellowish red ant about $\frac{3}{16}$ inch long that frequents houses in such numbers at times. Several other species occur in houses, but in this latitude the little red ant is the most annoying, as a rule.



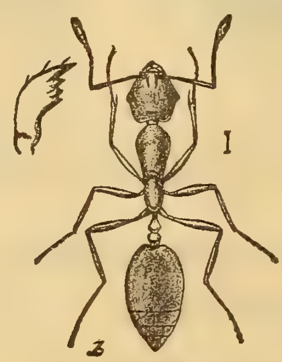


FIG. 65 Little red ant: *a* female; *b* neuter or worker—enlarged (after Riley)

Treatment: destroy colony with carbon bisulfid when possible. This is done by using a broom handle to make holes in the nest a few inches deep and several inches apart, pour-

ing in each about a teaspoonful of carbon bisulfid, then covering the nest with a damp blanket and in a few minutes exploding the fumes collected beneath with a light on the end of a short pole. Attract to sponge filled with sweetened water and kill the collected ants by dropping them in hot water.

74 **Cheese skipper** (*Piophila casei*). Whitish, jumping

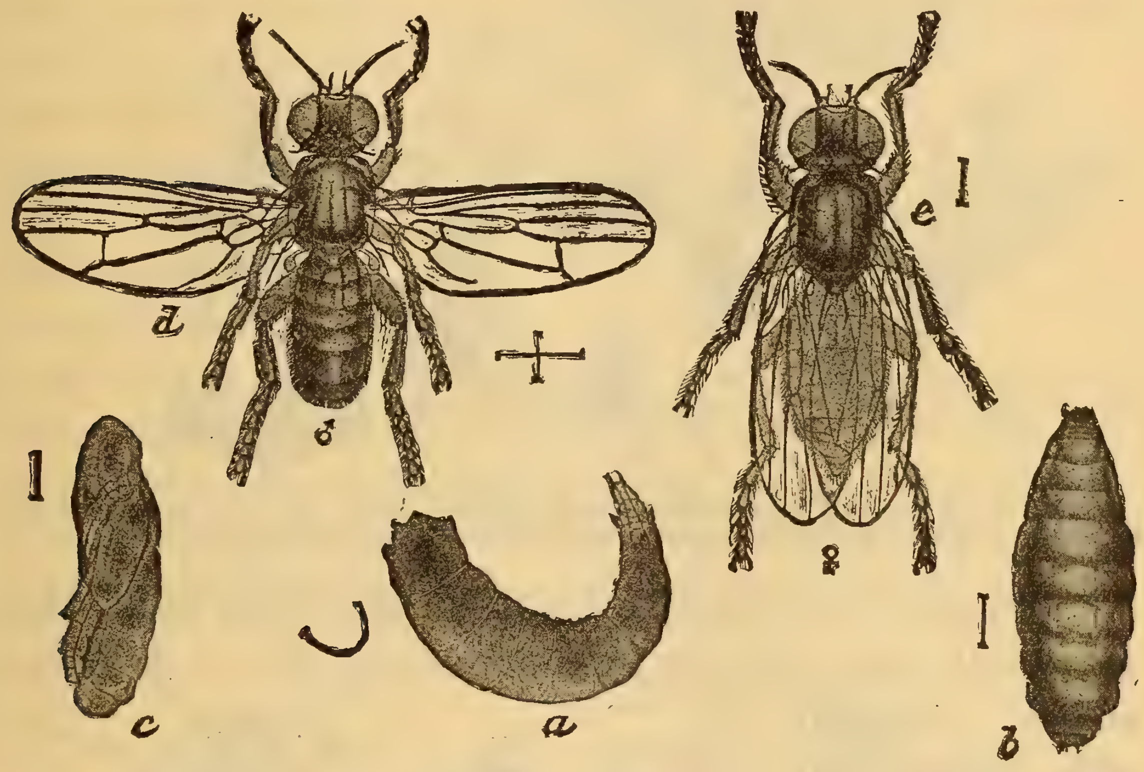


FIG. 66 Cheese skipper: *a* larva; *b* puparium; *c* pupa; *d* male fly; *e* female with wings folded—all enlarged (after Howard, U. S. dep't agr., div. ent., bull. 4, n. s.)

maggots are sometimes found infesting cheese. The parent insect is a small black fly less than $\frac{1}{2}$ inch long. This insect will also attack hams, and occasionally causes serious loss.

Treatment: exclude flies with netting, using 24-to-the-inch mesh. Cleanliness will render cheese factories less inviting to the flies. Hams and cheese stored in darkness are much less liable to infestation.

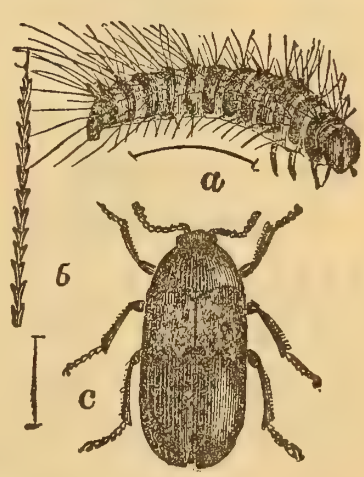


FIG. 67 Bacon beetle: *a* larva, enlarged; *b* larval bristle, greatly enlarged; *c* beetle

75 **Bacon beetle** (*Dermestes lardarius*). A dark brownish beetle about $\frac{5}{16}$ inch long with yellowish band across the base of the wing covers. The larva is brown, hairy, about $\frac{5}{8}$ inch long. Both

adult and larva attack bacon, meat, etc. The life cycle can be completed in about six weeks.

Treatment: cleanliness and excluding insects from the food.

76 **Croton bug** (*Phyllodromia germanica*). This is the smaller, light brown roach about $\frac{3}{4}$ inch long found in houses. It is very prolific, and is the species that is more abundant in cities.

FIG. 68 Croton bug: *a*, *b*, *c*, *d* successive immature stages; *e* adult; *f* adult female with egg case; *g* egg case enlarged; *h* adult with wings spread—all natural size except *g* (after Riley)

Treatment: roach poisons, such as Hooper's fatal food. Paris green with sugar has been used successfully, but is a dangerous poison. Fumigate with sulfur where possible. Entice the bugs to enter vessels partly filled with stale beer from which no escape is provided.

77 **Cockroach** (*Periplaneta orientalis*). This is the larger dark brown species an inch or more long, found in dwellings. It was much less wary than the preceding form.

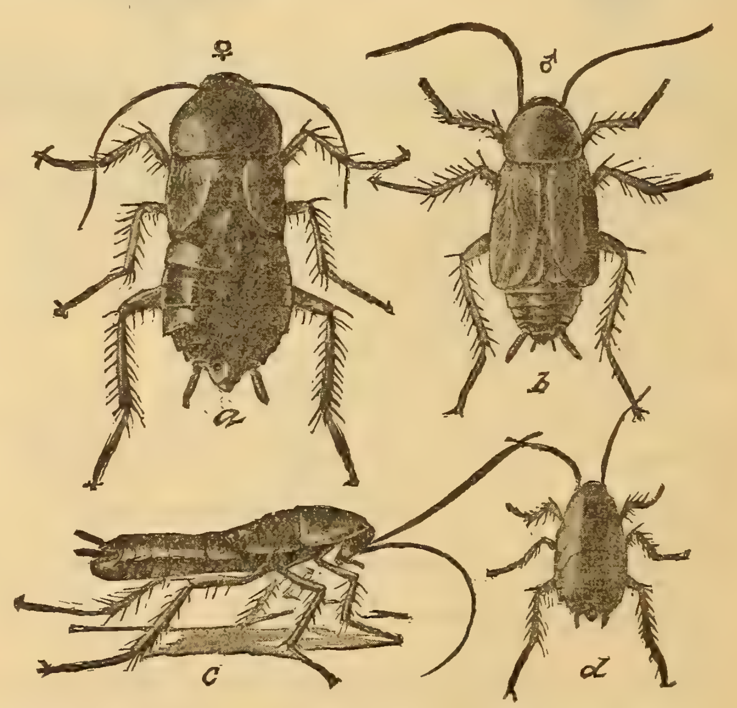


FIG. 69 Cockroach: *a* and *c* female; *b* male; *d* half-grown specimen—all natural size (after Marlatt, U. S. dep't agr., div. ent., bull. 4, n. s.)

Treatment: same as for the croton bug.

INSECTS AFFECTING STORED FOOD PRODUCTS

78 **Grain moth** (*Sitotroga cerealella*). A small caterpillar about $\frac{7}{16}$ inch long working in various grains and producing a whitish moth with a wing spread of a little over $\frac{1}{2}$ inch.

Treatment: fumigate infested grain with carbon bisulfid, and treat suspected granaries in the same manner.

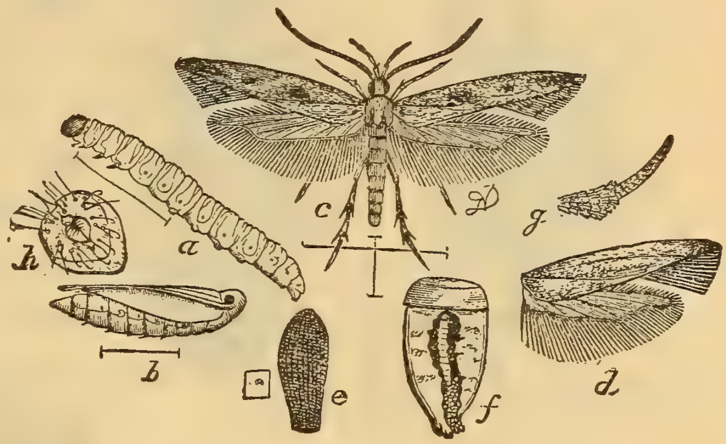


FIG. 70 Grain moth: *a* larva; *b* pupa; *c* moth; *d* wings of a paler variety; *e* egg; *f* kernel of corn showing work of larva; *g*, *h* other structural details—all enlarged except *f* (after Riley)

79 **Saw-toothed grain beetle** (*Silvanus surinamensis*). A small, brown, slender beetle about $\frac{1}{8}$ inch long found infesting cereals and dried food products. A common and prolific species which may complete its life cycle in 24 days, and may produce seven generations within a year.

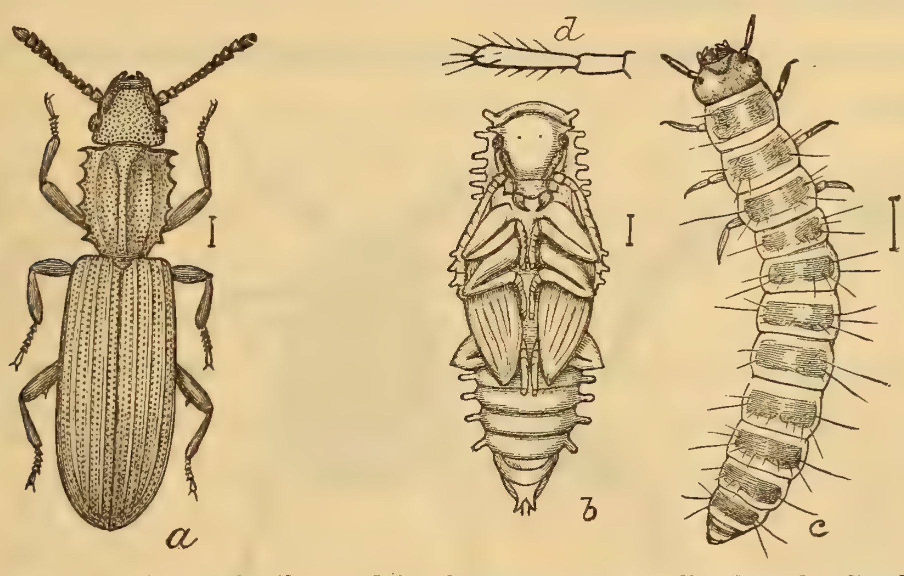


FIG. 71 Saw-toothed grain beetle: *a* adult; *b* pupa; *c* larva—all enlarged (after Chittenden, U. S. dep't agr., div. ent., bull. 4, n. s.)

Treatment: fumigate infested cereals with carbon bisulfid, and allow none of its food to lie long undisturbed.

80 **Confused flour beetle** (Tribolium confusum). A rather stout, shining, reddish brown beetle about $\frac{3}{16}$ inch long which attacks a large number of cereals and cereal products.

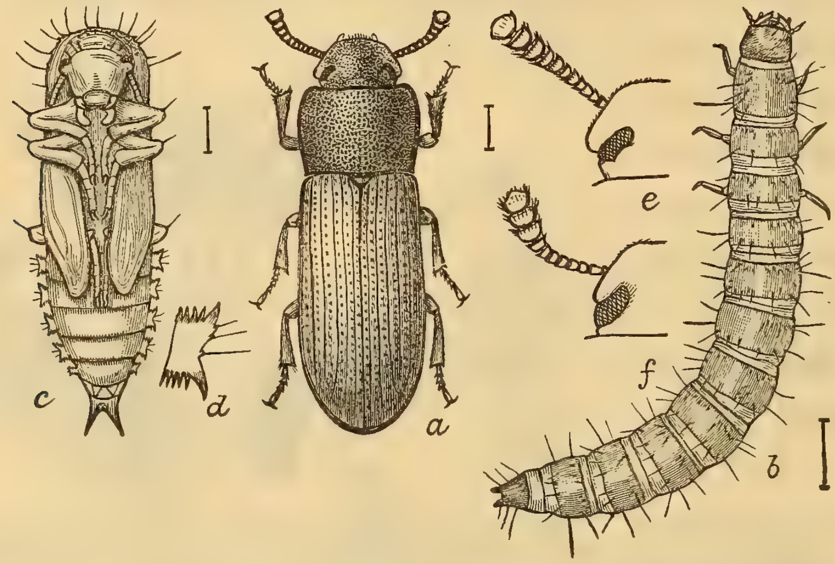


FIG. 72 Confused flour beetle: *a* beetle; *b* larva; *c* pupa—all enlarged; *d*, *e*, *f* minor parts enlarged (after Chittenden, U. S. dep't agr., div. ent., bull. 4, n. s.)

Very prolific, and frequently causes considerable injury. The life cycle may be completed in 36 days, but in cool weather this period is much prolonged.

Treatment: fumigate with carbon bisulfid, and clean infested localities.

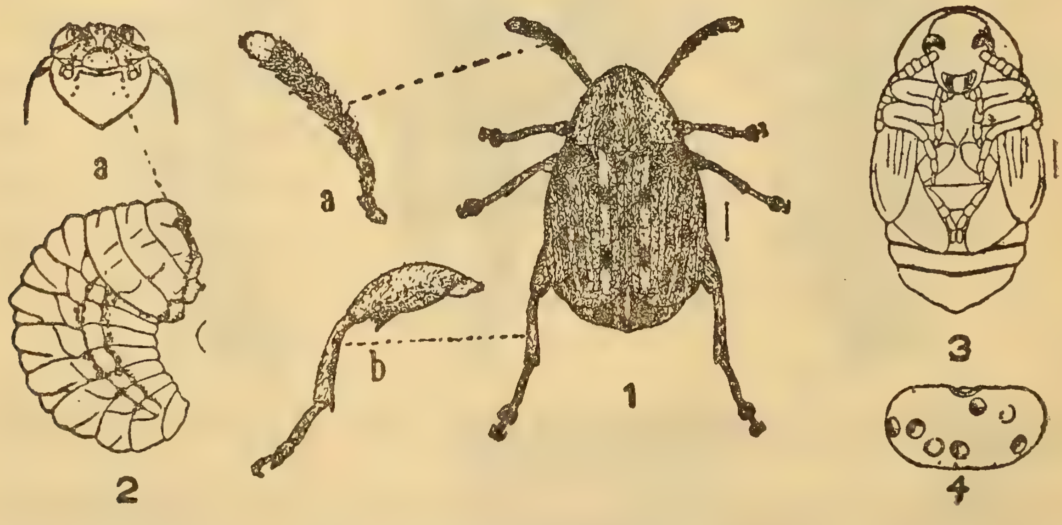


FIG. 73 The bean weevil: 1, beetle; 1*a* antenna, greatly enlarged; 1*b* hind leg enlarged; 2, larva, 2*a* larval head enlarged to show mouth parts; 3, pupa; 4, bean burrowed by the insect

81 **Bean weevil** (Bruchus obtectus). Small grayish brown beetles about $\frac{1}{8}$ inch long breeding in dry beans and eating out numerous holes. This insect attacks beans in the field by

preference, but frequently it will be found riddling the dried, stored beans.

Treatment: fumigate beans in all infested localities with carbon bisulfid as soon as threshed.

82 **Pea weevil** (*Bruchus pisorum*). Brownish or black beetles with indistinct white markings, about $\frac{3}{16}$ inch long, infesting peas. Habits about the same as those of the preceding species, except that it attacks peas.

Treatment: same as for bean weevil.

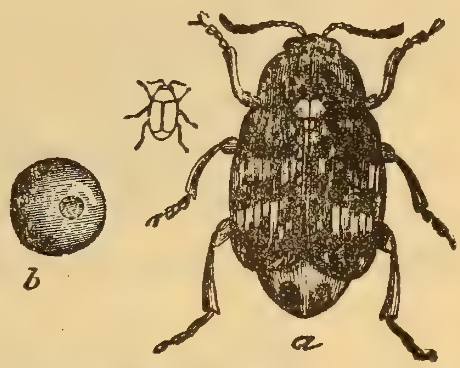


FIG. 74 Pea weevil: *a* natural size and enlarged; *b* a pea containing weevil

BENEFICIAL INSECTS

83 **Silk worm** (*Bombyx mori*). One case showing eggs, larva, single and double cocoons, those from which moths have emerged, one from which the silk has been reeled, male and female moths and the raw silk; also several other silk spinners and their cocoons, as follows: cocoons and moth of American silk worm, *Telea polyphemus*; cocoon and pupa of *Antheraea yamamai*, a Japanese silk worm; moth of *Antherae pernyi*, a Chinese silk worm; cocoon and moth of *Samia cynthia*, a domesticated silk worm which feeds mostly on the ailanthus tree.

84 **Pollen carriers.** A great many insects convey pollen from flower to flower, and in certain cases there are some very interesting adaptations. Some of the more common pollen-carriers are

FIG. 75 Wasp, enlarged (after Riley)

FIG. 76 Syrphus fly, adult—enlarged

honey bees, bumble or humble bees, other bees, wasps, flower or Syrphus flies and many others. The importance of this class of insects and their work is hardly appreciated, yet without their aid it would be practically impossible for us to raise most fruits, simply because no man or group of men would have time to fertilize, in the limited time available for such work, anywhere near all the blossoms which are attended to without previous thought or preparation on the part of man.

85 **Lady bugs.** Certain species are exceedingly valuable agents in controlling plant lice, which they and their young feed on. The

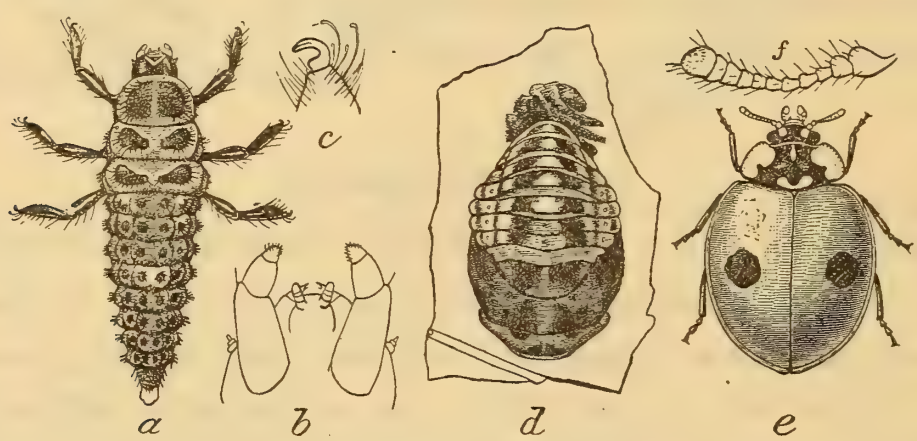


Fig. 77 Two spotted lady bug: *a* larva; *b* mouth parts of same; *c* claw of same; *d* pupa; *e* adult; antenna of same (reduced after Marlatt, U. S. dep't agr., div. ent., circ. 7, 2d s.)

larvae, or grubs, are usually dark colored, marked with yellow, and among hop-growers are known as "niggers." Some forms prey on scale insects.

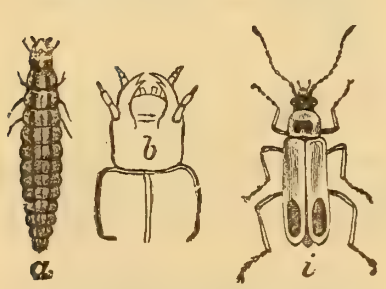


Fig. 78 The Pennsylvania soldier beetle: *a* larva; *b* its head, enlarged; *i* beetle

86 **Soldier beetles** (Chauliognathus species). These beetles are among the pollen-carriers, and the larvae prey on the worm of the codling moth.

87 **Syrphus flies.** The adults are usually seen among flowers, but the work of their frequently brightly colored larvae in reducing the number of plant lice is not so well known. These beneficial maggots are somewhat conical in shape, and may be found among colonies of plant lice.

Fig. 79 Larva of a Syrphus fly

88 **Lace-winged flies** (Chrysopa species). The delicate green, gauzy winged adults are beautiful creatures. The voracious, active larvae are veritable aphis lions, and may be seen in con-

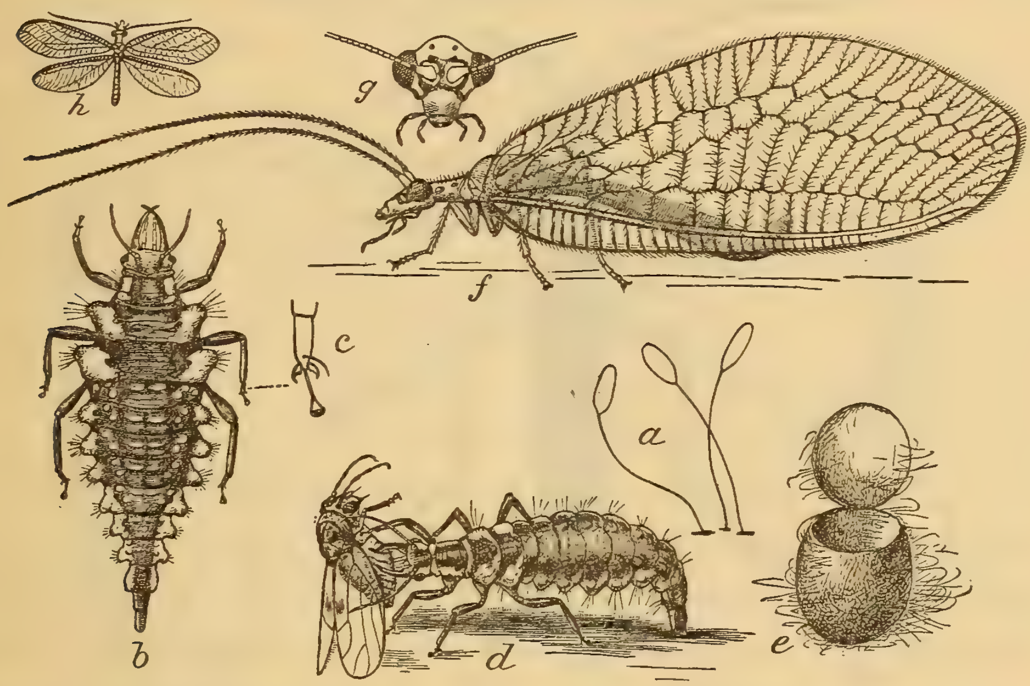


FIG. 80 Lace-winged fly Chrysopa oculata Say: *a* eggs; *b* full-grown larva; *c* foot of same; *d* same devouring a Psylla; *e* cocoon; *f* adult insect; *g* head of same; *h* adult, natural size (reduced after Marlatt, U. S. dep't agr., div. ent., circ. 7, 2d s.)

siderable numbers on trees infested with aphids. The eggs, curiously placed on the end of a slender stalk, always excite admiration in the beholder.

89 **Spined soldier bug** (Podisus spinosus). Represents a number of species which prey on other insects. This one feeds on a number of common pests, such as the potato beetle, elm leaf beetle and asparagus beetle grubs. One is frequently seen with a grub of the elm leaf beetle or asparagus beetle on its extended beak.

FIG. 81 Spined soldier bug: *a* beak or proboscis enlarged; *b* insect with one wing extended

90 **Pimpla** (Pimpla conquisitor). This species is one of the most valuable of the hymenopterous parasites, and represents a large class of parasites which render good service in keeping many pests under control. It was reared

in large numbers from the forest tent-caterpillar this past season, and it preys on a number of other very injurious insects.

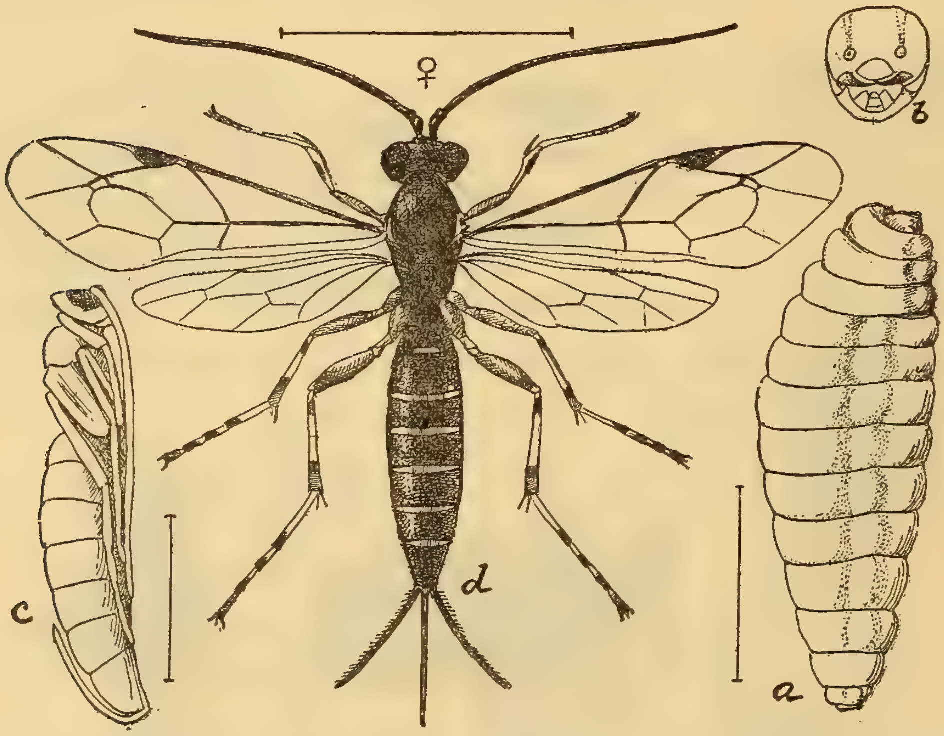


FIG. 82 Pimpla conquisitor: *a* larva; *b* head of same; *c* pupa; *d* adult female, all enlarged (after Howard, U. S. dep't agr., div. ent., tech. ser., no. 5)

91 Red tailed Tachina fly (Winthemia 4-pustulata). A most valuable parasite of the army worm, tent-caterpillar and several other pests. This fly has been observed in considerable numbers in fields badly infested with army worms, and is doubtless a most efficient parasite in keeping this pest under control.

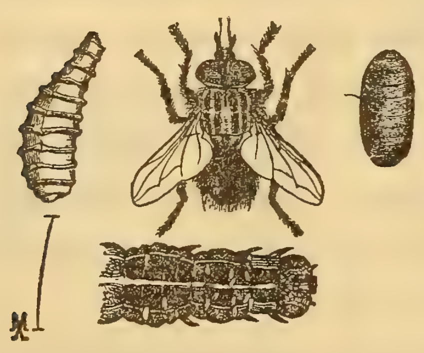


FIG. 83 Red tailed Tachina fly: larva, fly and puparium; also its eggs placed on the fore part of an army worm

FORMULAS

Internal poisons like paris green are used only against insects which devour their food. Place where they must be eaten if the plant is attacked and on nothing soon to be used for human food. Much depends on the thoroughness with which the application is made.

Paris green 1 pound, lime 1 pound, water 100 to 300 gallons, or dry 1 pound to 75 of plaster or flour. *London purple* and *paragrene* may be used in the same manner.

Arsenite of lime. Dissolve 1 pound white arsenic, 4 pounds sal soda (washing soda, carbonate of soda) in 1 gallon water by boiling in an iron vessel 15 minutes, or till the arsenic dissolves, leaving only a little muddy sediment. Add water lost in boiling, use 1 pint of this solution to 40 gallons water, to which has been added 2 pounds freshly slacked lime, or add 1 pint of the solution to 40 gallons bordeaux mixture.

Arsenate of lead. Dissolve 11 ounces acetate of lead (sugar of lead) in 4 quarts water and 4 ounces arsenate soda (50% purity) in 2 quarts of water, each lot in a wooden pail, then add solutions to 100 to 150 gallons water. May be used much stronger without injury to plants, and is unexcelled for use against insects which feed for a considerable time, as does the elm leaf beetle. It will not burn the foliage, even if applied in very large amounts, and will adhere for an indefinite period, in spite of rains. Prepare as directed above, or use one of the paste forms on the market; the latter are better than the dry or crystalline article.

Poisoned baits. Dip fresh clover or other attractive leaves in strongly poisoned water and place in infested localities. 1 pound paris green, 50 pounds bran, sweetened with molasses or cheap sugar, mixed to a soft mash with water is very attractive to grasshoppers. 20 pounds dry middlings, 1 pound paris green, is good for cutworms.

Poison carrier.[1] Heat 1 pint fish oil or cheap animal oil except tallow, 5 pounds pulverized resin in iron kettle with 1 gallon water till resin softens; then add lye solution (1 pound concentrated lye dissolved as for soap); stir thoroughly; add 4 gallons water and boil 2 hours, or till mixture will unite with cold water, making a clear, amber colored liquid. Add water to make 5 gallons. Use 1 gallon of the solution to 16 gallons water, and add 3 gallons milk of lime and ¼ pound paris green.

Contact insecticides are effectual only when applied directly to soft bodied insects, and the results will be proportional to the number of insects actually hit with the insecticide.

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1 Recommended by Mr Sirrine for poisoning insects on cabbage.

Hellebore (fresh) 1 ounce, water 3 gallons. May also be applied dry. In the latter event it should be mixed with flour several hours before it is used.

Pyrethrum or *insect powder* (fresh) 1 ounce, water 3 gallons. It may be used dry diluted with flour, and should then be mixed several hours before it is used.

Kerosene emulsion. ½ pound hard soap, 1 gallon boiling water, 2 gallons kerosene, dissolve soap in water, add kerosene and emulsify. Or, for limestone regions, 2 gallons kerosene, 1 gallon sour milk; emulsify. Dilute 4–25 times before using. A 10% mechanical kerosene emulsion may be used in place of either of the above.

Petroleum emulsion. A 20% mechanical emulsion of crude petroleum can be applied to fruit trees just before the buds start without injury, and it will result in killing most, if not all, San José scale, provided the application has been thorough.

Whale oil soap. 1½ to 2 pounds to 1 gallon of water for winter use, 1 pound to at least 4 gallons water for summer use.

Ivory soap. 5 cent cake to 8 gallons water is perhaps the best solution that can be used on house plants for scale insects, plant lice, etc.

Hot water, tobacco in solution or as dust are valuable contact insecticides.

Washes for borers. 1 pint crude carbolic acid (½ pint refined), 1 gallon soft soap, thin with 1 gallon hot water, stir in acid, let it set over night, then add 8 gallons soft water. Or to a saturated solution of washing soda add soft soap to make a thick paint; this is improved by 1 pint crude carbolic acid and ½ pound paris green to 10 gallons of wash. Or in 6 gallons saturated solution of washing soda, dissolve 1 gallon soft soap, add 1 pint carbolic acid, mix thoroughly, slake enough lime in 4 gallons water, so that when added, a thick whitewash will result, then add ½ pound paris green, mix thoroughly. The latter is probably the best. Valuable only to prevent egg-laying on bark.

Fumigation. Most valuable for young nursery stock and for grains. Cyanid of potassium (98% pure) 1 ounce, commercial sul

furic acid, 1 ounce by measure, water 3 ounces by measure, these amounts for 150 cubic feet of space; expose trees at least ½ hour. Prepare tight chamber, mix acid and water by pouring acid slowly, stirring frequently, into the water. Use earthen or glass vessels, and drop cyanid into the diluted acid, closing chamber at once. Small fruit trees in orchards can be fumigated under a tent before the buds start, using 1 pound of the cyanid to 100 cubic feet space, without injury to the trees, and this will result in killing most, if not all, the San José scale.

Carbon bisulfid 1 pound to 1000 cubic feet space; place in shallow dishes near *top* of chamber.

These substances are deadly poisons, the acid will corrode or eat many things, carbon bisulfid is inflammable and explosive in the presence of *any fire. Handle all with extreme care.*

Insecticide and fungicide. The poisoned bordeaux mixture is a most valuable combined insecticide and fungicide and is rapidly coming into favor. The bordeaux mixture may be prepared as follows: dissolve 6 pounds of copper sulfate (blue vitrol) by putting it in a bag of coarse cloth and hanging this in a vessel containing 4 to 6 gallons of water. For this purpose use an earthen or wooden vessel. After the copper sulfate is dissolved, dilute with water to 25 gallons. Slake four pounds of lime and add 25 gallons of water and then mix the two and keep thoroughly stirred while using. When applied on peach foliage, it is advisable to use an additional 2 pounds of lime. To each 50 gallons of bordeaux mixture as prepared above, add four ounces of paris green, london purple or paragrene. The amount of arsenite of lime solution to be used with bordeaux mixture is given on page 45. Arsenate of lead can also be used in the same amounts with this fungicide as with water. Bordeaux mixture alone is an excellent substance to apply to plants attacked by flea beetles, and when poisoned, forms one of the best general purpose sprays.

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The superior figure points to the exact place on the page in ninths; e. g. 34^3 means page 34 beginning in the third ninth of the page, i. e. about one third of the way down.

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KEY TO THE LAND MAMMALS

OF

Northeastern North America

BY

GERRIT S. MILLER JR

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1900

CONTENTS

KEY TO THE LAND MAMMALS OF NORTH-EASTERN NORTH AMERICA

INTRODUCTION

Originally outlined as part of my recently published *Preliminary list of the mammals of New York*[1], this "key" soon grew to the proportions of an independent paper. As first planned it was intended to furnish a ready means for finding—with the minimum of technical requirements—the name of any wild mammal taken in New York. When the "key" was separated from the "list" its scope was extended to include the entire mammalian fauna of the Atlantic slope of North America north of the southern boundary of the upper austral zone. At the same time the whales and porpoises were omitted. It is thus practically a key to the land mammals of the Atlantic division of the life zones represented in New York state, since the upper austral zone is the southernmost of these, and the arctic zone, florally at least, may almost be said to touch the higher Adirondack peaks. Throughout I have endeavored to write as non-technically as the subject will permit, that is to use no unexplained terms not to be found in a pocket dictionary.

Life zones

While the subject of life zones has been dealt with at considerable length in the paper just referred to, a few words of definition are necessary here. A life zone is simply an extended area over which the fauna and flora are relatively homogeneous. As such areas are limited chiefly by temperature, and their boundaries consequently determined by isothermal lines, they normally assume the form of belts stretching from east to west, or, to speak more exactly, arranged concentrically around the poles. Therefore in passing from pole to equator a certain number of these belts must be crossed. The forms of the life zones are distorted by irregularities in the surface of the earth with their accompanying variations in temperature. In the northern hemisphere mountain chains

1 Bulletin of the New York state museum no. 29. Nov. 1899.

carry the northern zones southward, and hot, dry plains bend the southern zones toward the north. Finally a zone may become locally broken into islands, as when a cool mountain chain is interrupted by warm valleys and plains, or cold swamps are scattered in hot lowlands. In North America there are seven of these life areas, each characterized by the predominance of a particular assemblage of animals and plants. Beginning at the north they are the arctic zone, Hudsonian zone, Canadian zone, transition zone, upper austral zone, lower austral zone and tropical zone. The last two lie south of the region included within the scope of this paper. The areas covered by the Atlantic divisions of the five others are as follows:

Arctic zone. Treeless northeastern coasts of Labrador and Newfoundland; above timber line on the highest mountain peaks of New England, and perhaps of the Adirondacks also.

Hudsonian zone. Wooded portions of Labrador, Newfoundland, northern Ontario, northern and eastern Quebec and northern New Brunswick; region immediately below timber line on the mountains of New England and New York and possibly in the highest southern Alleghanies.

Canadian zone. Eastern Nova Scotia; the greater part of New Brunswick; southern Quebec; eastern central Ontario; northern and western Maine; the higher parts of New Hampshire, Vermont and western Massachusetts; the Adirondacks, Catskills and higher parts of the Alleghanies.

Transition zone. Western Nova Scotia; eastern and southern Maine; southern Ontario (except north shore of Lake Erie); the greater part of the lowlands of New York, Vermont, New Hampshire, Massachusetts, Connecticut and Pennsylvania; the lower slopes of the Alleghanies to their extreme southern limit.

Upper austral zone. North shore of Lake Erie in southern Ontario; south shore of Lake Ontario, "lake region", lower Hudson valley and western end of Long Island in New York; southern Connecticut; lowlands of New Jersey, Delaware, eastern Pennsylvania, eastern Maryland and northeastern Virginia; belt (extending northeast and southwest) in Virginia, North Carolina, South Carolina and Georgia, covering the higher land east of the mountains.

Species and subspecies

In this paper subspecies are treated as the component parts of species, not, as is now too often the custom, as independent forms intergrading with species. The relationship of species and subspecies is thus maintained exactly parallel with that between genus and subgenus or family and subfamily.[1] The separate keys to the subspecies under each species will help to emphasize this conception. I have attempted to apply a system of English names that will coincide with this treatment of species and subspecies, but in certain cases perfect adherence to this principle has not been possible.

General plan of the key

Beginning with the definition of the class Mammalia, this paper consists of a series of keys and definitions, interspersed with brief statements of range, habitat and extent of groups. Keys are given under each order to its families, under each family to its genera, under each genus to its species and under each species to its subspecies. Suborders, subfamilies and subgenera are not included in this scheme, but their characters are referred to in the sections of the keys or elsewhere, and their names are inserted in the synopsis placed before the "key" proper (p. 65–76). Under each species and subspecies will be found references to, 1) the first publication of the specific or subspecific name, 2) first use of the binomial or trinomial combination, and 3) a recent monographic paper in which the form is described in detail. Absence of the second reference shows that the binomial or trinomial was used by the original describer of the form, or that it is now for the first time published. Absence of the third reference, in cases where the second and third are

[1] An example may make the matter more clear. Squirrels of the genus Sciurus occur throughout the greater part of the wooded portion of the northern hemisphere. The species vary much in form, and the variations tend to group themselves in such a way that the different groups are recognizable as subgenera, all, however, falling within the definition of the genus Sciurus. To the one of these groups of species containing the type species of the genus the name Sciurus in a subgeneric sense is restricted. It happens that this subgenus Sciurus is confined to the old world, and that within our limits the genus is represented by the three subgenera Tamiasciurus, Neosciurus and Parasciurus. No one would on this account deny that the genus Sciurus occurs in eastern North America. A species of this genus, Sciurus ludovicianus, is widely distributed in the southern United States. Individuals of this species vary considerably in size and color, and the variations so group themselves that several subspecies are recognizable, each restricted to a particular part of the range of the species, and all included within the definition of the species. The one of these which was first named (that of the Mississippi valley) and which consequently gives its name to the species as a whole, is not found east of the Alleghanies, where it is replaced by S. ludovicianus vicinus. The species Sciurus ludovicianus is nevertheless as truly a member of the fauna of the eastern United States as is the genus Sciurus.

not identical, shows that nothing of importance has been published on the animal during the present phase of the study of North American mammals, a period dating from 1889. The type locality of each form is given in parenthesis after the first reference. The accented syllable of all technical names is marked with an acute accent; and the derivation of each name is placed in parenthesis at the end of the diagnosis (Lat.=Latin, N. Lat.=New Latin, Gk.=Greek). All measurements are in millimeters followed (in parenthesis) by an approximate equivalent in inches and sixteenths.

As in the *List of the mammals of New York*, my aim is to present the subject as it stands today rather than to attempt to reach final conclusions. Numerous forms are therefore admitted the status of which is still in question. Though this course has its disadvantages, it seems the one least open to objection at the present time, when any revisionary work would necessarily be imperfect.

The use of keys in botany and zoology is now too well understood to require any special explanation. It must be remarked, however, that no keys can be made by which single specimens of closely related subspecies can be invariably named. Certain species even differ from each other by characters that can not be set down in a single line of print. I have endeavored to base keys and diagnoses on the most tangible characters available; but where the way is hard for the specialist it can not be made easy for the beginner.

Individuals affected with albinism, melanism and other abnormalities frequently occur in all species. Compared with the place they hold in popular estimation their interest is slight. They should be carefully guarded against as extremely liable to cause difficulty in identification. Such individuals seem possessed of a peculiar faculty for bringing themselves to notice.

SYNOPSIS[1]

Class **MAMMALIA**: mammals, p. 76
Subclass **METATHERIA**: marsupials, p. 76
Order **MARSUPIALIA**: marsupials, p. 77–78
Suborder **POLYPROTODONTIA**: polyprotodont marsupials
Family **DIDELPHIDIDAE**: opossums, p. 77–78
Genus **Didelphis** Linnaeus: p. 78

1 **Didelphis virginiana** Kerr: opossum, p. 78
Represented by:
Didelphis virginiana virginiana Kerr: northeastern opossum, p. 78

Subclass **EUTHERIA**: placental mammals, p. 76
Order **UNGULATA**: hoofed mammals, p. 78
Suborder **ARTIODACTYLA**: even-toed hoofed mammals, p. 78
Family **BOVIDAE**: cattle, p. 79
Genus **Bison** Hamilton Smith: p. 79

2 **Bison bison** (Linnaeus): American bison, p. 79
Represented by:
Bison bison bison (Linnaeus): American plains bison, p. 79
Family **CERVIDAE**: deer, p. 79
Genus **Rangifer** Hamilton Smith: p. 80

3 **Rangifer caribou** (Gmelin): woodland caribou, p. 80

4 **Rangifer terraenovae** Bangs: Newfoundland caribou, p. 81

5 **Rangifer arcticus** (Richardson): barren ground caribou, p. 81
Genus **Alces** Jardine: p. 81

6 **Alces americanus** Jardine: eastern moose, p. 81
Genus **Cervus** Linnaeus: p. 82

7 **Cervus canadensis** (Erxleben): east American wapiti, p. 82
Genus **Odocoileus** Rafinesque: p. 82

8 **Odocoileus americanus** (Erxleben): Virginia deer, p. 82
Represented by:
Odocoileus americanus americanus (Erxleben): southern Virginia deer, p. 83
Odocoileus americanus borealis Miller: northern Virginia deer, p. 83

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1 The arrangement of the higher groups is that adopted by Flower and Lydekker.

Order **GLIRES**: rodents, p. 83
Suborder **SIMPLICIDENTATA**: true rodents, p. 84
Family **SCIURIDAE**: squirrels, p. 84
Genus **Sciurus** Linnaeus: p. 85
Subgenus **Tamiasciurus** Trouessart: p. 85

9 **Sciurus hudsonicus** Erxleben: red squirrel, p. 85
Represented by:
Sciurus hudsonicus hudsonicus Erxleben: Hudsonian red squirrel, p. 86
Sciurus hudsonicus gymnicus Bangs: Canadian red squirrel, p. 85
Sciurus hudsonicus loquax Bangs: southeastern red squirrel, p. 86

Subgenus **Neosciurus** Trouessart: p. 85

10 **Sciurus carolinensis** Gmelin: gray squirrel, p. 86
Represented by:
Sciurus carolinensis carolinensis Gmelin: southeastern gray squirrel, p. 86
Sciurus carolinensis leucotis Gapper: northeastern gray squirrel, p. 87

Subgenus **Parasciurus** Trouessart: p. 85

11 **Sciurus ludovicianus** Custis: fox squirrel, p. 87
Represented by:
Sciurus ludovicianus vicinus Bangs: northern fox squirrel, p. 87

Genus **Tamias** Illiger: p. 88

12 **Tamias striatus** (Linnaeus): eastern chipmunk, p. 88
Represented by:
Tamias striatus striatus (Linnaeus): southeastern chipmunk, p. 88
Tamias striatus lysteri (Richardson): northeastern chipmunk, p. 88

Genus **Arctomys**: Schreber: p. 89

13 **Arctomys monax** (Linnaeus): woodchuck, p. 89
Represented by:
Arctomys monax monax (Linnaeus): southeastern woodchuck, p. 89
Arctomys monax canadensis (Kuhl): northeastern woodchuck, p. 89

14 **Arctomys ignavus** Bangs: Labrador woodchuck, p. 89

Genus **Sciuropterus** F. Cuvier: p. 90

15 **Sciuropterus volans** (Linnaeus): southern flying squirrel, p. 90

Represented by:

Sciuropterus volans volans (Linnaeus): southern flying squirrel, p. 90

16 **Sciuropterus sabrinus** (Shaw): northern flying squirrel, p. 90

Represented by:

Sciuropterus sabrinus sabrinus (Shaw): Hudsonian flying squirrel, p. 91

Sciuropterus sabrinus macrotis Mearns: Canadian flying squirrel, p. 91

Family **CASTORIDAE**: beavers, p. 91

Genus **Castor** Linnaeus: p. 35

17 **Castor canadensis** Kuhl: American beaver, p. 92

Represented by:

Castor canadensis canadensis Kuhl: northeastern beaver, p. 92

Castor canadensis carolinensis Rhoads: southeastern beaver, p. 92

Family **MURIDAE**: mice, p. 92

Subfamily **MURINAE**: old world mice, p. 93

Genus **Mus** Linnaeus: p. 94

18 **Mus musculus** Linnaeus: house mouse, p. 94

19 **Mus rattus** Linnaeus: black rat, p. 95

20 **Mus decumanus** Pallas: house rat, p. 95

Subfamily **CRICETINAE**: new world mice, p. 93

Genus **Reithrodontomys** Giglioli: p. 95

21 **Reithrodontomys lecontii** (Audubon & Bachman): harvest mouse p. 95

Represented by:

Reithrodontomys lecontii impiger Bangs: Virginia harvest mouse, p. 96

Genus **Oryzomys** Baird: p. 96

22 **Oryzomys palustris** (Harlan): ricefield mouse, p. 96

Represented by:

Oryzomys palustris palustris (Harlan): northern ricefield mouse, p. 96

Genus **Peromyscus** Gloger: p. 96

Subgenus **Peromyscus** Gloger: p. 96

23 **Peromyscus canadensis** (Miller): Canadian white-footed mouse, p. 97

Represented by:

Peromyscus canadensis abietorum Bangs: Hudsonian white-footed mouse, p. 97

Peromyscus canadensis canadensis (Miller): Canadian white-footed mouse, p. 97

Peromyscus canadensis nubiterrae (Rhoads): Cloud-land white-footed mouse, p. 98

24 **Peromyscus leucopus** (Rafinesque): deer mouse, p. 98

25 **Peromyscus maniculatus** (Wagner): Labrador white-footed mouse, p. 98

Subfamily **NEOTOMINAE**: wood rats, p. 93

Genus **Neotoma** Say & Ord: p. 98

Subgenus **Neotoma** Say & Ord: p. 98

26 **Neotoma pennsylvanica** Stone: Allegheny cave rat, p. 99

Subfamily **MICROTINAE**: voles and lemmings, p. 93

Genus **Synaptomys** Baird: p. 99

Subgenus **Synaptomys** Baird: p 99

27 **Synaptomys cooperi** Baird: Cooper's lemming, p. 100

28 **Synaptomys fatuus** Bangs: Bangs's lemming, p. 100

Subgenus **Mictomys** True: p. 99

29 **Synaptomys innuitus** (True): True's lemming, p. 100

30 **Synaptomys sphagnicola** Preble: Preble's lemming, p. 100

Genus **Dicrostonyx** Gloger: p. 101

31 **Dicrostonyx hudsonius** (Pallas): Labrador lemming, p. 101

Genus **Fiber** Cuvier: p. 101

32 **Fiber zibethicus** (Linnaeus): muskrat, p. 101

Represented by:

Fiber zibethicus zibethicus (Linnaeus): northeastern muskrat, p. 101

Fiber zibethicus aquilonius Bangs: Labrador muskrat, p. 102

33 **Fiber obscurus** Bangs: Newfoundland muskrat, p. 101

Genus **Microtus** Schrank: p. 101

Subgenus **Pitymys** McMurtrie: p. 102

34 **Microtus pinetorum** (Le Conte): pine mouse, p. 103
Represented by:
Microtus pinetorum scalopsoides (Audubon and Bachman): northern pine mouse, p. 103
Subgenus **Microtus** Schrank: p. 103

35 **Microtus terraenovae** Bangs: Newfoundland vole, p. 104

36 **Microtus chrotorrhinus** (Miller): rock vole, p. 104
Represented by:
Microtus chrotorrhinus chrotorrhinus (Miller): southern rock vole, p. 104
Microtus chrotorrhinus ravus Bangs: Labrador rock vole, p. 105

37 **Microtus breweri** (Baird): Muskeget island vole, p. 105

38 **Microtus enixus** Bangs: Hamilton inlet vole, p. 105

39 **Microtus pennsylvanicus** (Ord): field mouse, p. 105
Represented by:
Microtus pennsylvanicus pennsylvanicus (Ord): common eastern field mouse, p. 106
Microtus pennsylvanicus labradorius Bailey: Labrador field mouse, p. 106
Microtus pennsylvanicus fontigenus (Bangs): northern field mouse, p. 107
Microtus pennsylvanicus acadicus Bangs: Acadian field mouse, p. 107

40 **Microtus nesophilus** Bailey: Gull island mouse, p. 107
Genus **Phenacomys** Merriam: p. 108

41 **Phenacomys celatus** Merriam: large yellow-faced phenacomys, p. 108

42 **Phenacomys latimanus** Merriam: small yellow-faced phenacomys, p. 108
Genus **Evotomys** Coues: p. 109

43 **Evotomys ungava** Bailey: ungava redbacked mouse, p. 109

44 **Evotomys carolinensis** Merriam: Carolina redbacked mouse, p. 109

45 **Evotomys proteus** Bangs: variable redbacked mouse, p. 110

46 **Evotomys gapperi** (Vigors): common redbacked mouse, p. 110
Represented by:
Evotomys gapperi gapperi (Vigors): eastern redbacked mouse, p. 110
Evotomys gapperi ochraceus Miller: Mount Washington redbacked mouse, p. 111

47 **Evotomys rhoadsi** (Stone): New Jersey redbacked mouse, p. 111
Family **DIPODIDIAE**: jerboas, jumping mice etc. p. 111
Subfamily **ZAPODINAE**: jumping mice, p. 111
Genus **Zapus** Coues: p. 112

48 **Zapus hudsonius** (Zimmermann): meadow jumping mouse, p. 112
Represented by:
Zapus hudsonius hudsonius (Zimmermann): northern meadow jumping mouse, p. 113
Zapus hudsonius americanus (Barton): southern meadow jumping mouse, p. 112
Zapus hudsonius ladas Bangs: Labrador meadow jumping mouse, p. 113

Genus **Napaeozapus** Preble: p. 113

49 **Napaeozapus insignis** Miller: woodland jumping mouse, p. 113
Represented by:
Napaeozapus insignis abietorum Preble: northern woodland jumping mouse, p. 114
Napaeozapus insignis insignis Miller: southern woodland jumping mouse, p. 114
Napaeozapus insignis roanensis Preble: mountain woodland jumping mouse, p. 114
Family **ERETHIZONTIDAE**: American porcupines, p. 115
Genus **Erethizon** F. Cuvier: p. 115

50 **Erethizon dorsatus** (Linnaeus): Canadian porcupine, p. 115
Suborder **DUPLICIDENTATA**: hares and pikas, p. 84
Family **LEPORIDAE**: hares, p. 115
Genus **Lepus** Linnaeus: p. 115
Subgenus **Lepus** Linnaeus: p. 116

51 **Lepus labradorius** Miller: Labrador arctic hare, p. 116

52 **Lepus bangsi** (Rhoads): Newfoundland arctic hare, p. 116

53 **Lepus americanus** Erxleben: American varying hare, p. 116
Represented by:
Lepus americanus struthopus Bangs: Nova Scotia varying hare, p. 117
Lepus americanus americanus Erxleben: northern varying hare, p. 117
Lepus americanus virginianus (Harlan): southern varying hare, p. 117
Subgenus **Sylvilagus** Gray: p. 116

54 **Lepus floridanus** Allen: cottontail, p. 118
Represented by:
Lepus floridanus transitionalis Bangs: northeastern cottontail, p. 118
Lepus floridanus mearnsi (Allen): eastern prairie cottontail, p. 118
Lepus floridanus mallurus (Thomas): southeastern cottontail, p. 119
Order **FERAE**: flesh-eaters, p. 119
Suborder **PINNIPEDIA**: seals and their allies, p. 120
Family **ROSMARIDAE**: walruses, p. 120
Genus **Rosmarus** Scopoli: p. 120

55 **Rosmarus rosmarus** (Linnaeus): Atlantic walrus, p. 120
Family **PHOCIDAE**: earless seals, p. 121
Genus **Cystophora** Nilsson: p. 121

56 **Cystophora cristata** (Erxleben): hooded seal, p. 121
Genus **Halichoerus** Nilsson: p. 121

57 **Halichoerus grypus** (Fabricius): gray seal, p. 122
Genus **Phoca** Linnaeus: p. 122
Subgenus **Pagophilus** Gray: p. 122

58 **Phoca groenlandica** Fabricius: harp seal, p. 122
Subgenus **Pusa** Scopoli: p. 122

59 **Phoca hispida** Schreber: ringed seal, p. 123
Subgenus **Phoca** Linnaeus, p. 122

60 **Phoca vitulina** Linnaeus: harbor seal, p. 123
Suborder **FISSIPEDIA**: true carnivores, p. 120
Family **FELIDAE**: cats, p. 123
Genus **Felis** Linnaeus: p. 123

61 **Felis oregonensis** Rafinesque: puma, p. 123

Represented by:

Felis oregonensis hippolestes Merriam: northern puma, p. 124

Genus **Lynx** Kerr: p. 124

Subgenus **Lynx** Kerr: p. 125

62 **Lynx canadensis** Kerr: Canada lynx, p. 126

63 **Lynx subsolanus** Bangs: Newfoundland lynx, p. 125

Subgenus **Cervaria** Gray: p. 125

64 **Lynx ruffus** (Gueldenstaedt): bay lynx, p. 125

Represented by:

Lynx ruffus ruffus (Gueldenstaedt): northeastern bay lynx, p. 125

65 **Lynx gigas** Bangs: Nova Scotia lynx, p. 126

Family **CANIDAE**: dogs, p. 126

Genus **Canis** Linnaeus: p. 126

66 **Canis albus** (J. Sabine): arctic wolf, p. 127

67 **Canis occidentalis** (Richardson): American wolf, p. 127

Genus **Vulpes** Richardson: p. 127

68 **Vulpes lagopus** (Linnaeus): arctic fox, p. 128

69 **Vulpes fulvus** (Desmarest): red fox, p. 128

Represented by:

Vulpes fulvus fulvus (Desmarest): southeastern red fox, p. 128

Vulpes fulvus rubricatus Bangs: Nova Scotia red fox, p. 128

70 **Vulpes deletrix** Bangs: Newfoundland red fox, p. 129

Genus **Urocyon** Baird: p. 129

71 **Urocyon cinereoargenteus** (Müller): gray fox, p. 129

Represented by:

Urocyon cinereoargenteus cinereoargenteus (Müller): eastern gray fox, p. 129

Family **MUSTELIDAE**: weasels, p. 129

Genus **Lutra** Brisson: p. 130

72 **Lutra hudsonica** (Desmarest): North American otter, p. 130

Represented by:

Lutra hudsonica hudsonica (Desmarest): northeastern otter, p. 130

Lutra hudsonica lataxina (F. Cuvier): southeastern otter, p. 131

73 **Lutra degener** Bangs: Newfoundland otter, p. 131
Genus **Gulo** Storr: p. 131

74 **Gulo luscus** (Linnaeus): wolverine, p. 131
Genus **Mustela** Linnaeus: p. 132

75 **Mustela pennanti** Erxleben: fisher, p. 132
Represented by:
Mustela pennanti pennanti Erxleben: eastern fisher, p. 132

76 **Mustela brumalis** Bangs: north Labrador marten, p. 132

77 **Mustela americana** Turton: eastern marten, p. 132

78 **Mustela atrata** Bangs: Newfoundland marten, p. 133
Genus **Putorius** Cuvier: p. 133
Subgenus **Lutreola** Wagner: p. 133

79 **Putorius vison** (Schreber): mink, p. 133
Represented by:
Putorius vison vison (Schreber): northeastern mink, p. 134
Putorius vison lutreocephalus (Harlan) southeastern mink, p. 134
Subgenus **Arctogale** Kaup: p. 133

80 **Putorius cicognanii** (Bonaparte): brown weasel, p. 134
Represented by:
Putorius cicognanii cicognanii (Bonaparte): eastern brown weasel, p. 135

81 **Putorius occisor** Bangs: slender-tailed weasel, p. 135

82 **Putorius noveboracensis** Emmons: New York weasel, p. 135
Represented by:
Putorius noveboracensis noveboracensis Emmons: white-bellied New York weasel, p. 136
Putorius noveboracensis notius Bangs: yellow-bellied New York weasel, p. 136
Genus **Mephitis** Cuvier: p. 136

83 **Mephitis mephitica** (Shaw): skunk, p. 136
Represented by:
Mephitis mephitica mephitica (Shaw): northeastern skunk, p. 137
Mephitis mephitica scrutator Bangs: southeastern skunk, p. 137
Family **PROCYONIDAE**: racoons, p. 137
Genus **Procyon** Storr: p. 137

84 **Procyon lotor** (Linnaeus): racoon, p. 137

Represented by:

Procyon lotor lotor (Linnaeus): northeastern racoon, p. 138

Family **URSIDAE**: bears, p. 138

Genus **Thalarctos** Gray: p. 138

85 **Thalarctos maritimus** (Phipps): polar bear, p. 139

Genus **Ursus** Linnaeus: p. 139

Subgenus **Euarctos** Gray: p. 139

86 **Ursus americanus** Pallas: black bear, p. 139

Represented by:

Ursus americanus americanus Pallas: eastern black bear, p. 139

Ursus americanus sornborgeri Bangs: Labrador black bear, p. 139

Order **INSECTIVORA**: insect-eaters, p. 140

Family **TALPIDAE**: moles, p. 140

Subfamily **TALPINAE**: true moles, p. 140

Genus **Scalops** Cuvier: p. 141

87 **Scalops aquaticus** (Linnaeus): naked-tailed mole, p. 141

Represented by:

Scalops aquaticus aquaticus (Linnaeus): northern naked-tailed mole, p. 141

Genus **Parascalops** True: p. 141

88 **Parascalops breweri** (Bachman): eastern hairy-tailed mole, p. 142

Genus **Condylura** Illiger: p. 140

89 **Condylura cristata** (Linnaeus): star-nosed mole, p. 141

Family **SORICIDAE**: shrews, p. 142

Genus **Blarina** Gray: p. 142

Subgenus **Blarina** Gray: p. 142

90 **Blarina brevicauda** (Gray): large blarina, p. 142

Represented by:

Blarina brevicauda brevicauda (Gray): northern large blarina, p. 143

Subgenus **Cryptotis** Pomel: p. 142

91 **Blarina parva** (Say): small blarina, p. 143

Represented by:

Blarina parva parva (Say): northern small blarina, p. 143

Genus **Sorex** Linnaeus: p. 143

Subgenus **Neosorex** Baird: p. 143

92 **Sorex albibarbis** (Cope): eastern marsh shrew, p. 144
Subgenus **Microsorex** Baird: p. 143
93 **Sorex hoyi** Baird: Hoy's shrew, p. 144
Subgenus **Sorex** Linnaeus: p. 143
94 **Sorex macrurus** Batchelder: big-tailed shrew, p. 144
95 **Sorex richardsoni** Bachman: Richardson's shrew, p. 144
96 **Sorex fumeus** Miller: smoky shrew, p. 145
97 **Sorex personatus** I. Geoffroy: masked shrew: p. 145
Represented by:
Sorex personatus lesueuri (Duvernoy): southern masked shrew, p. 146
Sorex personatus personatus I. Geoffroy: northern masked shrew, p. 145
Sorex personatus miscix Bangs: Labrador masked shrew p. 146
Order **CHIROPTERA**: bats, p. 146
Suborder **MICROCHIROPTERA** true bats, p. 146
Family **VESPERTILIONIDAE**: typical bats, p. 146
Subfamily **VESPERTILIONINAE**: simple-nosed typical bats, p. 146
Genus **Lasiurus** Gray: p. 147
98 **Lasiurus cinereus** (Beauvois): hoary bat, p. 147
99 **Lasiurus borealis** (Müller): red bat, p. 147
Represented by:
Lasiurus borealis borealis (Müller): northern red bat, p. 148
Genus **Nycticeius** Rafinesque: p. 148
100 **Nycticeius humeralis** Rafinesque: Rafinesque's bat, p. 148
Genus **Myotis** Kaup: p. 148
101 **Myotis subulatus** (Say): Say's bat, p. 149
Represented by:
Myotis subulatus subulatus (Say): eastern Say's bat, p. 149
102 **Myotis lucifugus** (Le Conte): little brown bat, p. 149
Represented by:
Myotis lucifugus lucifugus (Le Conte): eastern little brown bat, p. 149
Genus **Lasionycteris** Peters: p. 149
103 **Lasionycteris noctivagans** (Le Conte): silvery bat, p. 149
Genus **Pipistrellus** Kaup: p. 150

104 **Pipistrellus subflavus** (F. Cuvier): American pipistrelle, p. 150
Represented by:
Pipistrellus subflavus subflavus (F. Cuvier): southeastern pipistrelle, p. 150
Pipistrellus subflavus obscurus Miller: northeastern pipistrelle, p. 150
Genus **Vespertilio** Linnaeus: p. 151

105 **Vespertilio fuscus** Beauvois: big brown bat, p. 151
Represented by:
Vespertilio fuscus fuscus Beauvois: eastern big brown bat, p. 151

KEY

Class **Mammalia** Mammals

Vertebrate (backboned) animals with four chambered heart, complete double circulation, body partly or wholly covered with hair (rarely almost naked); young nourished for a period after birth by milk; breathing accomplished by means of lungs (Mammália; Lat., a nipple).

The Mammalia are distributed over practically the whole surface of the earth and throughout the oceans. They are absent however from the most extreme arctic and antarctic regions. The class is divided into three subclasses: 1) the Prototheria, in which the young are hatched from eggs as in birds, confined to New Guinea, Australia, and Tasmania; 2) the Metatheria, in which the young are born in a very rudimentary condition and after birth carried for some time attached to the nipples of the parent (usually in a special pouch of skin); and 3) the Eutheria, in which the young are born perfectly formed. While the Metatheria comprise the one order Marsupialia, a single representative of which occurs within our limits, the Eutheria are divided by Flower and Lydekker[1] into 9 orders. Of these 7 are terrestrial, and members of each are found in North America. Six come within the scope of the present paper.

ORDERS

Female generally (always in North American species) provided with an external pouch in which the young are carried for sometime after birth, Metatheria (in species found within our limits, tail prehensile, teeth 50, hind foot with 5 toes, the innermost of which is thumb-like and clawless) (opossums).... Marsupialia, p. 77

1 An introduction to the study of mammals living and extinct. 1891.

Female without external pouch for carrying the young, Eutheria (in species found within our limits, tail never prehensile, teeth less than 50, innermost toe of hind foot never thumb-like)
  Fore limbs modified to serve as wings (bats).......... Chiroptera, p. 146
  Fore limbs not modified to serve as wings
    Toes armed with hoofs (bison, deer etc.)........... Ungulata, p. 78
    Toes armed with claws
      Front teeth chisel-shaped and separated from grinding teeth by a wide space (gnawing animals).................................. Glires, p. 83
      Front teeth not chisel-shaped, tooth row essentially continuous
        Brain large, well developed; in species found within our limits, size large, length 300 (12) to 2400 (96), eyes well developed, muzzle not greatly elongated (flesh-eaters) Ferae, p. 119
        Brain small, not highly developed; in species found within our limits, size small, length under 250 (10), eyes small or rudimentary, muzzle greatly elongated (moles, shrews, etc.)............................... Insectivora, p. 140

Order **Marsupialia** *Marsupials*

Two small separate bones projecting from front of pelvis; female reproductive organs double through greater part of their length; young not attached to parent before birth by a complicated special organ (placenta) but born in a very undeveloped condition and carried for some time in an external pouch of skin in which are situated the nipples; brain very small and simple; in North American species tail prehensile, teeth 50, hind foot with five toes, the innermost of which is clawless and thumb-like. (Marsupiália; Lat., a pouch)

The order Marsupialia reaches its greatest development in Australia and the neighboring islands. Elsewhere it is confined to South America and the warmer parts of North America. Eight families are recognized, six of which are peculiar to the Australian region. The other two are confined to America. One of them reaches our limits.

Family **Didelphididae** *Opossums*

Teeth 50; toes five, distinct, each provided with a well developed claw except the first on hind foot, which is thumb-like and clawless. Tail long, prehensile, mostly naked and scaly. (Didelphididae; genus Didelphis)

The family Didelphididae is peculiar to the warmer parts of America. It contains about 10 genera, all strictly tropical with the exception of the following:

Genus **Didelphis** Linnaeus

1758 Didelphis Linnaeus, Systema naturae. ed. 10. 1:21. Type Didelphis marsupialis Linnaeus.

Size of a house cat; fur a mixture of short, fine, soft hairs and long coarse bristles; pouch always well developed; fifth toe on hind foot markedly shorter than second, third and fourth, which are subequal. (Didélphis; Gk., two womb)

The genus Didelphis is peculiar to the warmer parts of America, it contains three or four species, one of which reaches our limits.

Didelphis virginiana Kerr *Common opossum*

1792 Didelphis virginiana Kerr, Animal kingdom. 1:193 (Virginia).

Blackish varied with grayish white; ears naked, leathery; tail dark at base, light at tip; total length 700 (27½), tail vertebrae 28 (11), hind foot 57 (2¼). (virginiána; N. Lat. Virginian)

The common opossum is abundant in woods and old fields throughout the austral zones of the eastern United States. At the northern limit of its range it is irregular in distribution. Notwithstanding the popular misconceptions on the subject the process of reproduction in the opossum is, with the exception of the one peculiarity common to the members of the subclass Metatheria, precisely as in our other mammals.

Order **Ungulata** *Hoofed animals*

Terrestrial, herbivorous or omnivorous animals with hoofed toes; front teeth variable in form (sometimes wanting in upper jaw) but never long and with chisel-like edges; cheek teeth with broad flat crowns for grinding vegetable matter. (Unguláta; Lat., a hoof)

The order Ungulata contains about a dozen families distributed practically throughout the world outside of Australia and the neighboring islands. Four of these occur in America north of Panama, and two have been found within our limits during historic times. The domestic horse, cow, sheep, and pig are well known representatives of the order. The North American members of the group belong to the suborder Artiodactyla, in which an even number of toes (usually two) are well developed in each foot.

FAMILIES OF UNGULATA

Horns simple, hollow, permanent.................................... Bovidae
Horns branched, solid, periodically shed.............................. Cervidae

Family **Bovidae** *Cattle, bison, sheep, etc.*

Horns permanent, consisting of a hollow sheath and solid bony core, canine teeth never present. (Bóvidae; Genus Bos)

The family Bovidae, containing the cattle, bison, sheep, true antelopes, and their allies, is represented by about 30 genera, chiefly African and Asiatic. Only one of the three genera occurring in America is confined to the western hemisphere. A single genus has inhabited northeastern North America within historic times.

Genus **Bison** Hamilton Smith

1827 Bison Hamilton Smith, Griffith's Cuvier, Animal kingdom. 5:373. Type Bos bison Linnaeus.

Forehead convex, much broader than long; horns placed in front of highest part of skull; head heavily clothed with long bushy hair. (Bíson; Lat., a bison)

Two living members of this genus are known, one peculiar to eastern Europe, the other to North America. The remains of several extinct species have been found in various parts of North America.

Bison bison (Linnaeus) *American bison*

1758 [Bos] bison Linnaeus, Systema naturae. ed. 10. 1:72 (Texas).
1891 B[ison] bison Jordan, Manual of the vertebrate animals of the northern United States. ed. 5, p. 337.

Horn core short (under 10 in. or 250 mm) very strongly curved, circumference at base much greater than length along upper curvature. (bíson; Lat. a bison)

The American bison, which formerly ranged throughout central North America, east to Pennsylvania and central New York, is now practically extinct, but the skulls and horn cores may be occasionally found in salt licks and other places once frequented by the animals. Our animal was the plains bison, B. bison bison, smaller and shorter horned than the woodland bison, B. bison athabascae Rhoads.

Family **Cervidae** Deer and their allies

Horns solid, shed and renewed each year, usually much branched, though occasionally (always in young) simple; canine teeth usually present in upper jaw. (Cérvidae; genus Cervus)

The family Cervidae contains 10 or more genera mostly of very wide distribution or peculiar to the old world. At least three are con-

fined to America. Four of the five that occur in America north of Panama have been found within our limits during historic times, and three of these are still represented.

GENERA OF CERVIDAE

Horns present in both sexes; nose entirely hairy (caribou) Rangifer, p. 80
Horns normally present in males only; nose partly or entirely naked
  Horns broadly flattened; a small naked space between nostrils (moose) .... Alces, p. 81
  Horns not conspicuously flattened; muzzle entirely naked
    Horns about 1530 (60) in length, their circumference at base about 200 (8) (wapiti) .... Cervus, p. 82
    Horns about 610 (24) in length, their circumference at base about 115 (4½) (deer) .... Odocoileus, p. 83

Genus **Rangifer** Hamilton Smith

1827 Rangifer Hamilton Smith, Griffith's Cuvier, Animal kingdom. 5:304. Type Cervus tarandus Linnaeus.

Horns long, much branched, usually flattened at tip; muzzle entirely hairy. (Rángifer; Old French, branch-bearer)

This genus, which includes the reindeer of the old world and the caribou of America, is represented within our limits by three species.

SPECIES OF RANGIFER

Muzzle and region about eye dark .... R. caribou
Muzzle and region about eye conspiciously whitish
  Size very large; antlers relatively short and heavy..R. terraenovae
  Size small; antlers relatively long and light.......... R. arcticus

Rangifer caribou (Gmelin) *Woodland caribou*

1788 [Cervus tarandus] γ. caribou Gmelin, Systema naturae. ed. 13. 1:177. (Eastern Canada).
1853 Rangifer caribou Audubon and Bachman, Quadr. N. Am. 3: 111.
1898 Rangifer tarandus caribou Lydekker, The deer of all lands, p. 42.

General color tawny brown; head and neck paler; front half of lower surface of body dark; *no white eye ring;* a narrow white ring on leg above hoof; horns large and heavy, *the prongs mostly pointing upward.* (cáribou; Indian name)

The woodland caribou is abundant in the forested region of the Hudsonian zone and uppermost part of the Canadian zone in eastern Canada. It reaches the eastern United States in northern Maine only.

Rangifer terraenovae Bangs *Newfoundland caribou*

1896 Rangifer terraenovae Bangs, Preliminary description of the Newfoundland caribou, Nov. 11, 1896. p. 2. (Codroy Newfoundland)
1898 Rangifer tarandus terraenovae Lydekker, The deer of all lands, p. 45.

General color drab; head and neck paler, *the muzzle and a large patch including eye conspicuously whitish;* legs whitish for some distance above hoofs; horns large and heavy, the prongs mostly pointing forward and inward. (terraenóvae; N. Lat., of Newfoundland)

The Newfoundland caribou is confined to the island of Newfoundland, from which it never crosses to the mainland. It is the largest species of caribou of eastern North America.

Rangifer arcticus (Richardson) *Barren ground caribou*

1829 Cervus tarandus var. arcticus Richardson, Fauna Boreali-Americana. 1: 241. (Barren grounds of arctic America)
1896 Rangifer arcticus Allen, Bull. Am. mus. nat. hist. 20 Nov. 1896. 8: 234.
1898 Rangifer tarandus arcticus Lydekker, The deer of all lands, p. 47.

General color light brown; head and neck paler, the muzzle and a large patch about eye conspicuously whitish; legs whitish for some distance above hoofs, *horns very long and slender,* the prongs mostly pointing inward; *size small, the female scarcely larger than a sheep.* (árcticus; Lat., arctic)

The barren ground caribou occurs in the treeless arctic regions of extreme northern America. Within our limits it is confined to the barrens of Labrador.

Genus **Alces** Jardine

1835 Alces Jardine, The naturalists library, 21 (mammalia; deer, antelope, camels, etc.): 125. Type Cervus alces Linnaeus.

Horns very greatly flattened and expanded; muzzle broad and elongated; a small naked spot between nostrils. (Álces; Lat., an elk)

The genus Alces, which contains the old world elk and the American moose, the largest living members of the deer family, is represented by one species within our limits.

Alces americanus Jardine *Eastern moose*

1835 Alces americanus Jardine, The naturalists library, 21 (mammalia deer, antelope, camels, etc.): 125. (Eastern Canada)
1898 Alces machlis Lydekker, The deer of all lands, p. 52. (part)

Dark brown, blackening on belly and paler on legs, shoulders and muzzle; hight at shoulders about 2000 (6 ft); spread of antlers, 1700 (5 ft), circumference of antler above bur, 215 (8½). (americánus; N. Lat., American)

The moose is an inhabitant of forests in the Canadian zone and lowermost edge of the Hudsonian zone. It is now exterminated in the east-

ern United States except in northern Maine, but is still found in the adjoining British provinces.

Genus **Cervus** Linnaeus

1758 Cervus Linnaeus, Systema naturae. 1, ed. 10. 1:66. Type Cervus elaphus Linnaeus.

Horns large, curved mostly backward, the tines all directed forward; first tine immediately above base; hoofs broad, tail short. (Cérvus; Lat., a deer)

The genus Cervus is confined to the temperate parts of the northern hemisphere. About half a dozen species are known, mostly peculiar to the old world. Two are now recognized as occurring in America; one of these has only recently been exterminated within our limits.

Cervus canadensis (Erxleben) *East American wapiti*

1777 [Cervus elaphus] canadensis Erxleben, Syst. regn. anim. 1:305. (Eastern Canada)

1822 Cervus canadensis Desmarest, Mammalgie. 2:433.

1898 Cervus canadensis Lydekker, The deer of all lands, p. 94.

Reddish brown, paler in winter; hight at shoulder, 1530 (5 ft); horns 1530 (5 ft) in length, 200 (8) in circumference above basal tine. (canadénsis; N. Lat., Canadian)

The east American wapiti is now extinct in the eastern United States and eastern Canada,[1] where, however, its antlers are often found in bogs and stream beds.

Genus **Odocoileus** Rafinesque

1832 Odocoileus Rafinesque, Atlantic journal. 1: 109. Type Odocóileus speleus Rafinesque.

Horns small, curved forward, the tines all directed upward; first tine some distance above base; hoofs narrow; tail rather long. (Odocóileus; Gk., tooth cave, Rafinesque's specimen having come from a cavern deposit)

The genus Odocoileus (often known as Cariacus or Dorcelaphus) numerous members of which occur in the western United States as well as in Mexico and South America, is represented within our limits by one species only.

Odocoileus americanus (Erxleben) *Virginia deer*

General color in summer uniform reddish, in winter usually grayer and faintly speckled; belly, inner side of legs, and under side of tail white. (americánus; N. Lat., American)

The Virginia deer occurs in all sufficiently extensive tracts of forest throughout eastern North America from the south Atlantic states to the warmer parts of the Canadian zone. It is divisible into two well marked subspecies.

1 It is possible that the animal still occurs in Quebec.

SUBSPECIES OF ODOCOILEUS AMERICANUS

Size medium; teeth relatively small (lower row of cheek teeth 75 (3) in length); gray winter coat not well developed.. O. americanus americanus

Size large; teeth relatively large (lower row of cheek teeth 85 (3⅜) in length); gray winter coat well developed...... O. americanus borealis

Odocoileus americanus americanus (Erxleben) *Southern Virginia deer*

1777 [Cervus dama] americanus Erxleben, Syst. regn. anim. 1:312. (Virginia)

Size medium; teeth small, the row of lower cheek teeth 75 (3) in length; *winter pelage not conspicuously grayer or coarser than summer pelage;* horns slender, 540 (21½) in length, 90 (3½) in circumference at base. (americánus; N. Lat., American)

The southern Virginia deer is an inhabitant of the austral zones. Its range is not at present understood in detail; and it may eventually be found that the animal does not enter our limits.

Odocoileus americanus borealis, subsp. nov.[1] *Northern Virginia deer*

Cariacus virginianus Auct. (not Cervus virginianus Boddaert, which is O. americanus americanus)

1898. Mazama americana Lydekker, The deer of all lands, p. 249. (part)

Size, large; teeth large, the row of lower cheek teeth 85 (3⅜) in length; *winter pelage coarse, usually much tinged with gray, very different from summer pelage;* horns robust, 540 (21½) in length, 120 (4¾) in circumference at base. (boreális; Lat., northern)

The northern Virginia deer is an inhabitant of the Canadian zone. It is abundant throughout northern New York, northern New England and southeastern Canada. The limits of its range are not known.

Order Glires *Rodents*

Front teeth long, chisel shaped; cheek teeth broad, short, flat-crowned; a wide toothless space between front teeth and cheek teeth. (Glí-res; Lat., a dormouse)

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1 Type, adult male (skin and skull) No. 4999, collection of E. A. and O. Bangs, Bucksport, Maine, 12 Dec. 1895. Collected by Alvah G. Dorr.

Some of the measurements of this specimen are as follows: total length, 1830 (6 ft); tail 280 (11 in.) (from fresh specimen by collector). Skull, greatest length 340 (13⅜), basal length, 310 (12¼), zygomatic breadth, 130 (5); length of upper tooth row, 83 (3¼); greatest width between outer sides of upper tooth row, 83 (3¼), lower tooth row, 83 (3¼).

The order Glires is essentially cosmopolitan. Its members may be recognized at a glance by their peculiar teeth. The group is usually divided into 21 families,[1] nine of which occur in North America. Six of these are found within our limits.

FAMILIES OF GLIRES

Upper front teeth four, the second pair minute and placed directly behind the first (hares, Duplicidentata)	Leporidae, p. 115
Upper front teeth two. (Simplicidentata)	
Tail very broad, flattened from above downward (beaver)	Castoridae, p. 91
Tail rounded or flattened from side to side	
Fur thickly sprinkled with stiff quills (porcupines)	Erethizontidae, p. 115
Fur without quills	
At least four well developed grinding teeth in each jaw; tail bushy (squirrels, etc.)	Sciuridae, p. 84
Never more than three well developed grinding teeth in each jaw; tail closely haired	
Hind feet not greatly elongated (rats, mice etc.)	Muridae, p. 92
Hind feet greatly elongated (jumping mice)	Dipodidae, p. 111

Family Sciuridae *Squirrels*

Upper front teeth two; upper cheek teeth four or five, lower cheek teeth four; a well developed bony projection on skull above and behind eye socket (postorbital process); tail round, covered with long hairs which are usually so arranged as to form a broad, flat brush. (Sciúridae; genus Sciurus)

The family Sciuridae is almost cosmopolitan in distribution. It is a large group, containing 15 or 20 genera. In North America it is represented by seven genera, four of which occur within our limits.

GENERA OF SCIURIDAE

Sides with a densely furred membrane joining front and hind legs (flying squirrels)	Sciuropterus, p. 90
Sides without membrane	
Form stout and clumsy; tail less than half as long as body; top of skull nearly flat (woodchucks)	Arctomys, p. 89
Form slender and graceful; tail much more than half as long as body; top of skull distinctly rounded	
Cheek pouches present; back striped (chipmunks)	Tamias, p. 88
Cheek pouches absent; back (in our species) without stripes (squirrels)	Sciurus, p. 85

1 Tullberg recognizes 27 families, but even this number is probably too small.

Genus Sciurus Linnaeus

1758 Sciurus Linnaeus, Systema naturae. ed. 10, 1: 63. Type Sciurus vulgaris Linnaeus.

Tail very long and bushy, the hairs longest on the sides; ears well developed, pointed, hairy; thumb with a rudimentary nail. (Sciúrus; Gk. shade tail)

The genus Sciurus, which is found in nearly all parts of the world except Australia and the neighboring islands, is well represented in North America, about 80 forms occurring north of Panama. Three species are found within our limits.

SPECIES OF SCIURUS

Size small, hind foot less than 50 (2); back red (red squirrels, subgenus Tamiasciurus)............. S. hudsonicus
Size medium or large, hind foot over 60 ($2\frac{3}{8}$); back not red
  Ears whitish (gray squirrels, subgenus Neosciurus). S. carolinensis
  Ears rusty brown (fox squirrels, subgenus Parasciurus) S. ludovicianus

Sciurus hudsonicus (Erxleben) *Red squirrel*

Size small; *back red, varying* much in exact shade; belly white or gray, never tawny in forms found within our limits. (hudsónicus; N. Lat., Hudsonian)

The well known red squirrel occurs throughout the wooded parts of northern North America. In different regions it has developed numerous well marked local races, three of which occur in eastern North America.

SUBSPECIES OF SCIURUS HUDSONICUS

Hind foot about 44 ($1\frac{3}{4}$); edge of tail reddish. S. hudsonicus gymnicus
Hind foot about 47 ($1\frac{7}{8}$); edge of tail yellowish or grayish
  Belly in winter pelage gray................ S. hudsonicus hudsonicus
  Belly always pure white. .... S. hudsonicus loquax

Sciurus hudsonicus gymnicus Bangs *Canadian red squirrel*

1899 Sciurus hudsonicus gymnicus Bangs, Proc. New England zool. club. 31 Mar. 1899. 1: 28. (Greenville (near Moosehead lake) Maine)

Colors dark and rich; outer fringe of tail distinctly *red;* belly white in summer, *dark gray in winter.* Total length, 290 ($11\frac{1}{2}$); tail vertebrae, 120 ($4\frac{3}{4}$); hind foot, 44 ($1\frac{3}{4}$). (gýmnicus; Lat., gymnastic)

The Canadian red squirrel inhabits the Canadian forests of eastern North America, south to northern New York.

Sciurus hudsonicus hudsonicus (Erxleben) *Hudsonian red squirrel*

1777 [Sciurus vulgaris] ε hudsonicus Erxleben, Syst. regn. anim. 1:416. (Hudson bay)

1894 Sciurus hudsonicus Allen, Bull. Am. mus. nat. hist. 7 Nov. 1894. 6:325.

1898 Sciurus hudsonicus Allen, Bull. Am. mus. nat. hist. 22 July 1898. 10:255.

Colors pale, outer fringe of tail *yellowish or grayish,* belly white in summer, dark gray in winter. Total length, 310 (21⅛); tail vertebrae, 118 (4⅝); hind foot, 47 (1⅞). (hudsónicus; N. Lat., Hudsonian)

The Hudsonian red squirrel is probably confined to the wooded portions of the Labrador peninsula.

Sciurus hudsonicus loquax Bangs *Southeastern red squirrel*

1896 Sciurus hudsonicus loquax Bangs, Proc. biolog. soc. Washington. 28 Dec. 1896. 10:161. (Liberty Hill Ct.)

1898 Sciurus hudsonicus loquax Allen, Bull. Am. mus. nat. hist. 28 July 1898. 10:257.

Colors pale; outer fringe of tail yellowish; *belly pure white at all seasons.* Total length, 315 (12½); tail vertebrae, 130 (5⅛); hind foot, 47 (1⅞). (lóquax; Lat., talkative)

The southeastern red squirrel occurs in the deciduous forests of the transition and upper austral zones of the eastern United States.

Sciurus carolinensis Gmelin *Gray squirrel*

Size medium; *back gray,* more or less tinged with yellowish; belly white, occasionally blotched with rusty; ears whitish. (carolinénsis; N. Lat., Carolinian)

The gray squirrel is a wide ranging species, divisible into numerous geographic races, two of which occur within our limits.

SUBSPECIES OF SCIURUS CAROLINENSIS

Hind foot about 60 (2⅜); back always strongly tinged with rusty yellowish................	S. carolinensis carolinensis
Hind foot about 70 (2¾); back in winter pelage clear gray....	S. carolinensis leucotis

Sciurus carolinensis carolinensis Gmelin *Southeastern gray squirrel*

1788 [Sciurus] carolinensis Gmelin, Systema naturae. ed. 13, 1 : 148.

1896 Sciurus carolinensis carolinensis Bangs, Proc. biolog. soc. Washington. 28 Dec. 1896. 10: 153.

Back dark yellowish rusty gray, *never clear gray* in any pelage. Total length, 455 (18); tail vertebrae, 205 (8); hind foot, 60 (2⅜). (c a r o l i n é n s i s; N. Lat., Carolinian)

The southeastern gray squirrel inhabits the austral zones of the eastern United States from New Jersey to northern Florida.

Sciurus carolinensis leucotis (Gapper) *Northeastern gray squirrel*

1830 S c i u r u s l e u c o t i s Gapper, Zoological journal. 5: 206. (Region between York and Lake Simcoe, Ontario)

1877 S c i u r u s c a r o l i n e n s i s var. l e u c o t i s Allen, Monogr. N. Am. rodentia, p. 706.

1896 S c i u r u s c a r o l i n e n s i s l e u c o t i s Bangs, Proc. biolog. soc. Washington. 28 Dec. 1896. 10: 155.

Back *clear silvery gray in winter pelage*, often tinged with yellowish brown in summer, belly occasionally with rusty blotches. Total length, 500 (19⅝); tail vertebrae, 220 (8½); hind foot, 70 (2⅝). (l e u c ó t i s; Gk., white ear)

The northeastern gray squirrel occurs in the deciduous forests of the transition zone and lowermost part of the Canadian zone in Pennsylvania, New York, New England and southeastern Canada. Wholly or partly black individuals are often met with.

Sciurus ludovicianus Custis *Fox squirrel*

Size medium; back always strongly tinged with rusty; *belly never pure white* (varying from bright rust color to rusty white; *ears rusty*). (l u d o v i c i á n u s; N. Lat., Louisianian)

The fox squirrel is confined to the forests of the austral zones and lower edge of the transition zone of eastern North America. Its western limit is not definitely known. Of the three or more races into which the species is divisible, only the following occurs within our limits. Partly or wholly black individuals are not uncommon.

Sciurus ludovicianus vicinus Bangs *Northern fox squirrel*

1896 S c i u r u s l u d o v i c i a n u s v i c i n u s. Bangs, Proc. biolog. soc. Washington. 28 Dec. 1896. 10: 150. (White Sulphur Springs, West Virginia)

Back mixed black and rusty; belly varying from pale rust color to rusty white; ears rusty. Total length, 590 (23¼); tail vertebrae, 270 (10½); hind foot, 73 (2⅞). (v i c í n u s; Lat., neighboring)

The northern fox squirrel is an inhabitant of the forests of the transition zone and upper austral zone east of the Alleghanies. It formerly occurred with considerable regularity as far north as central New York and southern New England, but it is now fast approaching extinction, specially in the northern part of its range. The western fox squirrel, S. l u d o v i c i a n u s l u d o v i c i a n u s, occupies the same zones in the region immediately west of the Alleghanies.

Genus Tamias Illiger

1811 Tamias Illiger, Prodr. syst. mamm. et. avium, p. 83. Type Sciurus striatus Linnaeus.

Like Sciurus, but with less bushy tail, and with well developed cheek pouches in which large quantities of food can be carried. *The only known species is conspicuously striped on the back*, while none of our squirrels are so marked. *Upper cheek teeth four* on each side, all well developed. (Tamías; Gk., a steward)

The genus Tamias is represented by one species only, the well known chipmunk of the eastern United States and southern Canada.

Tamias striatus (Linnaeus) *Eastern chipmunk*

Reddish brown or yellowish brown; *back with five black stripes and two whitish ones.* (striátus; Lat., striped)

The eastern chipmunk occurs throughout eastern North America from the lower edge of the upper austral zone to the lower edge of the Hudsonian zone. It is divisible into four geographic races, two of which occur within our limits.

SUBSPECIES OF TAMIAS STRIATUS

Rump rich rufous brown.................................T. striatus striatus
Rump pale, dull, yellowish brown...................... T. striatus lysteri

Tamias striatus striatus (Linnaeus) *Southeastern chipmunk*

1758 [Sciurus] striatus Linnaeus, Systema naturae. ed. 10. 1: 64. (Southeastern United States)

1857 Tamias striatus Baird, 11th Smithsonian report, p. 35.

1886 Tamias striatus Merriam, American naturalist. Mar 1886. 20: 242.

Colors dark and rich; rump warm rufous brown, or chestnut. Total length, 250 ($9\frac{7}{8}$); tail vertebrae, 90 ($3\frac{9}{16}$); hind foot, 33 ($1\frac{5}{16}$). (striátus; Lat., striped)

The southeastern chipmunk inhabits the old fields and open woods of the upper austral zone. It is abundant from the lower Hudson valley south to North Carolina.

Tamias striatus lysteri (Richardson) *Northeastern chipmunk*

1829 Sciurus (Tamias) lysteri Richardson, Fauna Boreali-Americana. 1: 182. (Penetanguishene, Ontario, Canada)

1886 Tamias striatus lysteri Merriam, American naturalist. Mar. 1886. 20: 242.

Color pale and dull, rump yellowish brown. Total length, 250 ($9\frac{7}{8}$); tail vertebrae, 95 ($3\frac{3}{4}$); hind foot 36 ($1\frac{7}{16}$).

The northeastern chipmunk inhabits clearings, old fields and open woods in the transition zone and lower part of the Canadian zone in the region east of Lake Huron and the upper Mississippi valley. It is abundant throughout the greater part of New York and New England.

Genus **Arctomys** Schreber

1780 Arctomys Schreber, Säugethiere. pl. 207.

Form stout and heavy; tail short, much less than half as long as body, densely covered with long, rather stiff hairs; upper cheek teeth five in each jaw, each, except first, with two transverse grooves on crown. (Árctomys; Gk., bear mouse)

The genus Arctomys occurs throughout the greater part of northern North America, Asia and alpine Europe. It is represented in North America by six or more species, two of which, the well known woodchuck or ground-hog, and a little known animal from Labrador, occur within our limits.

SPECIES OF ARCTOMYS

Fur much suffused with reddish and yellowish; skull long and narrow, smooth above .... A. monax
Fur slightly suffused with reddish and yellowish; skull short and broad, with a well developed median ridge over brain case .... A. ignavus

Arctomys monax (Linnaeus) *Common woodchuck*

1758 [Mus] monax Linnaeus, Systema naturae. ed. 10.1:60. (Maryland)
1780 Arctomys monax Schreber, Säugethiere. 4:737.

Grizzly gray, varied with chestnut, yellowish and blackish; under parts reddish; skull long and narrow, the top smooth. Total length, 460 (18); tail vertebrae, 115 (4½); hind foot, 75 (3). (Mónax; Lat., a hermit)

The common woodchuck is an abundant animal throughout the Hudsonian, Canadian, transition and upper austral zones in eastern North America from Labrador and Hudson bay south at least to Virginia. Two races probably occur in this region, but their characters are not well understood. The southern form is A. monax monax, the northern A. monax canadensis (Erxleben) (See Allen, Bull. Am. mus. nat. hist. 10 Nov. 1898. 10:456.) Partly or wholly black individuals are often met with.

Arctomys ignavus Bangs *Labrador woodchuck*

1899 Arctomys ignavus Bangs, Proc. New England zool. club. 28 Feb. 1899. 1:13. (Black bay, Labrador)

Dark grizzly gray, little varied with yellowish and reddish; *skull short and broad, the braincase developing a well marked median ridge* in adult individuals. Total length, 500 (19⅝); tail vertebrae, 140 (5½); hind foot, 80(3¼). (ignávus; Lat., inactive)

The Labrador woodchuck is at present known from Black bay, Labrador only.

Genus **Sciuropterus** F. Cuvier

1855 Sciuropterus F. Cuvier, Dents des mammifères, p. 255. Type Sciurus volans Linnaeus.

Squirrels with a broad furry membrane connecting front and hind leg of each side, but none between hind legs. (Sciurópterus; Gk., squirrel wing)

The genus Sciuropterus is distributed throughout the greater part of northern Europe, northern Asia and northern North America. It contains a dozen or more species, several of which are American. Two occur within our limits.

SPECIES OF SCIUROPTERUS

Total length about 280 (11); fur of belly dark at base.......... S. sabrinus
Total length about 230 (9); fur of belly white to base.......... S. volans

Sciuropterus volans (Linnaeus) *Southern flying squirrel*

1758 [Mus] volans Linnaeus, Systema naturae. ed. 10. 1:63. (Virginia)
1890 S[ciuropterus] volans Jordan, Manual of the vertebrate animals of the northern United States. ed. 5. p. 324.
1896 Sciuropterus volans volans Bangs, Proc. biolog. soc. Washington. 28 Dec. 1896. 10:164.

Back drab, somewhat shaded with russet, not distinctly different in winter and summer; *belly pure white to extreme base of hairs.* Total length 230 (9); tail vertebrae, 100 (4); hind foot, 30 (1¼). (vólans; Lat., flying)

The southern flying squirrel occurs in woods, orchards, buildings, etc., in the transition zone and upper austral zone from New Hampshire and southern Ontario to Georgia. It is divisible into two races; of which the typical form alone, S. volans volans, occurs within our limits.

Sciuropterus sabrinus (Shaw) *Northern flying squirrel*

Back in winter glossy wood brown mixed with cinnamon, in summer sooty drab; *belly dirty white, the hairs darker at base.* (sabrínus; N. Lat., Severn)

The northern flying squirrel occurs throughout the wooded portions of eastern North America from the southern border of the Canadian zone northward. It is abundant in the evergreen forests of central and northern New York and New England, and in the Alleghanies. Two subspecies occur within our limits.

SUBSPECIES OF SCIUROPTERUS SABRINUS

Size large, hind foot over 40 ($1\frac{9}{16}$) ; ear short and broad .... S. sabrinus sabrinus
Size medium, hind foot under 40 ($1\frac{9}{16}$) ; ear long and narrow .... S. sabrinus macrotis

Sciuropterus sabrinus sabrinus (Shaw) *Hudsonian flying squirrel*

1801 Sciurus sabrinus Shaw, Gen. zool. 1 : 157. (Severn river, James bay)
1898 Sciuropterus sabrinus Mearns, Proc. U. S. nat. mus. 4 Nov. 1889. 21 : 353.

Total length, 350 ($13\frac{3}{4}$) ; tail vertebrae, 140 ($5\frac{1}{2}$) ; hind foot, 42 ($1\frac{11}{16}$) ; ear from crown, 15 ($\frac{5}{8}$). (sabrínus; N. Lat., Severn)

The Hudsonian flying squirrel is confined to the Hudsonian forests of eastern and central Canada.

Sciuropterus sabrinus macrotis Mearns *Canadian flying squirrel*

1896 Sciuropterus sabrinus Bangs, Proc. biolog. soc. Washington. 28 Dec. 1896. 10 : 162.
1898 Sciuropterus sabrinus macrotis Mearns, Proc. U. S. nat. mus. 4 Nov. 1898. 21: 353. (Catskill mts, N. Y.)

Total length, 280 (11) ; tail vertebrae, 125 (5) ; hind foot, 38 ($1\frac{1}{2}$) ; ear from crown, 20 ($\frac{3}{4}$). (macrótis; Gk., long eared)

The Canadian flying squirrel is abundant in the Canadian forests of the northeastern United States and southeastern Canada.

Family **Castoridae** *Beavers*

Four broad, rootless cheek teeth in each jaw; angle of lower jaw rounded; *tail very broad, flattened from above downward, scaly ;* size large. (Castóridae; genus Castor)

The family Castoridae is represented by a single living genus common to the northern parts of both old and new worlds.

Genus **Castor** Linnaeus

1758 Castor Linnaeus, Systema naturae. ed. 10. 1 : 58. Type Castor fiber Linnaeus.

Feet four-toed; hind feet webbed; second toe of hind foot double-clawed. (Cástor; Lat., a beaver)

One species of beaver occurs in North America. It is closely related to that of the old world.

Castor canadensis Kuhl *American beaver*

Flat space on top of skull between eye sockets distinctly longer than broad. (canadénsis; N. Lat., Canadian)

The American beaver, which occurs throughout the wooded parts of North America, is divisible into four or more races, two of which are found within our limits.

SUBSPECIES OF CASTOR CANADENSIS

Scaly portion of tail more than twice as long as wide.. C. canadensis canadensis
Scaly portion of tail less than twice as long as wide.. C. canadensis carolinensis

Castor canadensis canadensis Kuhl *Northeastern beaver*

1820 Castor canadensis Kuhl, Beiträge zur zool. u. vergl. anat. p. 64. (Eastern Canada)

1898 Castor canadensis Rhoads, Trans. Am. philos. soc. n. s. Oct. 1898. 19:418.

Scaly portion of tail more than twice as long as wide; pelage long, full and soft. Total length, 1100 (35); tail vertebrae, 410 (16¼); hind foot, 175 (6⅞). (canadénsis; N. Lat., Canadian)

The northeastern beaver was formerly an inhabitant of the wooded banks of lakes and watercourses in the Hudsonian and Canadian zones of eastern Canada and the northeastern United States. It has been exterminated south of the Canadian border.

Castor canadensis carolinensis Rhoads *Southeastern beaver*

1898 Castor canadensis carolinensis Rhoads, Trans. Am. philos. soc. n. s. Oct. 1898. 19:420.

Scaly portion of tail less than twice as long as wide; pelage relatively short and harsh. Total length, 1100 (35); hind foot, 180 (7). (carolinénsis; N. Lat., Carolinian)

The southern beaver inhabits the austral zones of the eastern United States. Its range is now restricted to the wilder foothills of the southern Alleghanies.

Family Muridae *Rats, mice, etc.*

Front teeth two; cheek teeth never more than three in each jaw. *In the species that occur within our limits the fur is without spines or bristles,* and the hind feet and legs are never greatly elongated for jumping. (Múridae; genus Mus)

The family Muridae, which includes more than one third of the existing rodents and a greater number of species than any other family of mammals, is cosmopolitan in distribution. It probably contains more than 100 genera, many of which are American, 11 occurring within our limits.

GENERA OF MURIDAE

Grinding teeth with tubercles arranged in three transverse rows very distinct in teeth of upper jaw (subfamily Murinae, old world rats and mice) .... Mus, p. 94

Grinding teeth with tubercles arranged in two rows, or without distinct tubercles of any kind

- Crowns of grinding teeth with tubercles arranged in two rows (subfamily Cricetinae, American rats and mice)
  - Upper front teeth grooved (harvest mice) Reithrodontomys, p. 95
  - Upper front teeth not grooved
    - Skull with a distinct ridge over eye-socket; fur coarse; belly not pure white; total length over 230 (9) (rice field mice) .... Oryzomys, p. 96
    - Skull without ridge over eye-socket; fur fine; belly pure white; total length under 215 ($8\frac{1}{2}$) (white-footed mice) .. Peromyscus, p. 96
- Crowns of grinding teeth divided into loops, or triangles formed by plates of hard enamel inclosing a softer substance (dentine)
  - Upper front teeth narrow, compressed, the antero-posterior diameter of each much greater than the transverse diameter; body slender, tail always long; eyes and ears large; belly white (subfamily Neotominae, wood rats and cave rats) .... Neotoma, p. 98
  - Upper front teeth broad, the antero-posterior diameter of each less than transverse diameter; body clumsy; tail usually short; eyes and ears small; belly generally not white (subfamily Microtinae, voles, lemmings, muskrats etc.)
    - Lower front teeth short, the roots terminating on inner side of grinding teeth (lemmings)
      - Upper front teeth grooved; ears small but well formed; color not changing to white in winter; tail covered with short hairs .... Synaptomys, p. 99
      - Upper front teeth not grooved, ears rudimentary; color white in winter, tail with a brush of stiff hairs nearly as long as itself .... Dicrostonyx, p. 101

Lower front teeth long, their roots extending under posterior grinding tooth into outer side of jaw (voles)
- Tail flattened laterally (muskrat) .... Fiber, p. 101
- Tail round
  - Grinding teeth without roots (prongs) .... Microtus, p. 102
  - Grinding teeth with roots (prongs) in adults
    - Grinding teeth heavy, with sharp-pointed angles; color never red.. Phenacomys, p. 108
    - Grinding teeth light, with blunt angles; color usually red .... Evotomys, p. 109

Genus **Mus** Linnaeus

1758 Mus Linnaeus, Systema naturae. ed. 10. 1: 59. Type Mus rattus Linnaeus.

Front teeth without grooves; cheek teeth in upper jaw with *tubercles of crown arranged in three* longitudinal rows; form slender; *tail long, scaly, scant haired;* fur coarse. (Lat., a mouse)

The genus Mus contains many old world species, but none native to America. Four have been naturalized in the United States. One of these, the roof rat, Mus alexandrinus (like the black rat but brown with a yellowish white belly) is normally confined to the lower austral zone. Two of the three others are well known within our limits.

SPECIES OF MUS

Total length under 200 (8) (mice) .... M. musculus
Total length over 300 (12) (rats)
- Color bluish black; tail more than half of total length M. rattus
- Color brownish; tail less than half of total length.... M. decumanus

Mus musculus Linnaeus *House mouse*

1758 [Mus] musculus Linnaeus, Systema naturae. ed. 10. 1 : 62. (Sweden)

Brownish gray, slightly paler below. Total length, 170 (6¾); tail vertebrae, 85 (3⅜); hind foot, 17 ( ). (músculus; Lat., a little mouse)

The house mouse is thoroughly established throughout the settled parts of America. It is abundant in buildings and cultivated fields within our limits, and is sometimes found in woods.

Mus rattus Linnaeus *Black rat*

1758 [Mus] rattus Linnaeus, Systema naturae. ed. 10. 1:61. (Sweden)

Blue black, darker on the back, more slaty on the belly. Total length, 400 (15¾); tail vertebrae, 215 (8½); hind foot, 37 (1 7/16). (ráttus; Lat., a rat)

The black rat was formerly widely spread in the eastern United States. It is now rapidly disappearing before the larger and stronger brown rat. This animal occurs still in central Massachusetts, but with this exception I know of no localities where it is now found abundantly in the northeastern United States.

Mus decumanus Pallas *House rat*

1778 Mus decumanus Pallas, Nov. sp. quadr. glir. ord. p. 91. (Russia)

Brownish above; *grayish beneath; tail scaly,* clothed with short stiff hairs, not distinctly bicolor. Total length, 400 (15¾); tail vertebrae, 180 (7⅛); hind foot, 45 (1¾). (decumánus; Lat., a tithe gatherer)

The house rat is abundant and well known throughout North America.

Genus Reithrodontomys Giglioli

1873 Reithrodontomys Giglioli, Richer. intorn. alla distrib. geogr. gener. p. 60. Type Mus lecontii Aud. and Bach.

Like Peromyscus except that the *face of each upper front tooth is marked by a conspicuous longitudinal groove.* (Reithrodóntomys; Gk., channel tooth mouse)

The genus Reithrodontomys is confined to North America. It reaches its greatest development in Mexico and the southwestern United States, where it is represented by 15 or more forms. Only one species occurs within our limits.

Reithrodontomys lecontii (Audobon and Bachman) *Harvest mouse*

1842 Mus lecontii Audobon and Bachman, Journ. Acad. nat. sci. Philadelphia. 8:307. (Georgia)

1895 Reithrodontomys lecontii Allen, Bull. Am. mus. nat. hist. May 21, 1895. 7:116.

Light brown above, varying much in exact shade; whitish beneath. (lecóntii; name from that of John LeConte)

The harvest mouse is common throughout the southeastern United States. Three races are now recognized: R. lecontii dickinsoni Rhoads from Florida; R. lecontii lecontii from the lower austral zone, and the following:

Reithrodontomys lecontii impiger Bangs *Virginia harvest mouse*

1898 Reithrodontomys lecontii impiger Bangs, Proc. biolog. soc. Washington. 10 Aug. 1898. 12 : 167. (White Sulphur Springs, W. Va.)

Russet brown above, dull white beneath. Total length, 115 ($4\frac{1}{2}$); tail vertebrae, 51 (2); hind foot 9 ($\frac{3}{8}$). (impíger; Lat., quick)

The little known Virginia harvest mouse has been taken at White Sulphur Springs W. Va. only. It probably occurs throughout the southern part of the upper austral zone, east of the high Alleghanies.

Genus **Oryzomys** Baird

1857 Oryzomys Baird, Mamm. N. Am. p. 458. Type Mus palustris Harlan.

Front teeth without grooves; cheek teeth with tubercles arranged in two rows; *skull distinctly ridged over eye sockets;* form slender; total length more than 230 (9); tail long, scant haired; belly not white. (Orýzomys; Gk., rice mouse)

The genus Oryzomys is widely distributed in the warmer parts of America. Many species are known, only one of which reaches the upper austral zone of the eastern United States.

Oryzomys palustris (Harlan) *Rice field mouse*

1837 Mus palustris Harlan, American jour. sci. 31 : 386. (Fast island, near Salem N. J.)

1857 Oryzomys palustris Baird, Mamm. N. Am. p. 459.

Dark brown above, paler below. Total length, 240 ($9\frac{1}{2}$) ; tail vertebrae, 115 ($4\frac{1}{2}$) ; hind foot, 30 ($1\frac{3}{16}$.) (palústris; Lat., pertaining to a marsh)

The ricefield mouse is locally common in marshes throughout the austral zones of the eastern United States, north to New Jersey. The form which occurs within our limits is the typical subspecies, O. palustris palustris. Two others are found in Florida and a fourth in Texas.

Genus **Peromyscus** Gloger

1842 Peromyscus Gloger, Gemeinn, Hand-u. hilfsbuch der naturgesch. p. 95. Type Peromyscus arboreus Gloger=Cricetus myoides Gapper=Mus sylvaticus noveboracensis Fischer.

Front teeth without grooves, cheek teeth in upper jaw with tubercles arranged in two longitudinal rows; *skull smoothly rounded between eye sockets;* form slender Total length, (in our species) under 220 ($8\frac{5}{8}$) ; tail long, well furred, belly white. (Peromýscus; Gk., little pocket mouse)

The genus Peromyscus, which contains nearly 100 species, is confined to America. It reaches its greatest development in Mexico and the western United States. Three species occur within our limits, all members of the subgenus Peromyscus.

SPECIES OF PEROMYSCUS

Tail about half of total length, ears large, colors dull or light.. P. canadensis
Tail less than half of total length, ears moderate, colors bright or dark
  Tail slightly less than half of total length, color strongly russet .... P. leucopus
  Tail considerably less than half of total length, color dull, not strongly russet.................................. P. maniculatus

Peromyscus canadensis (Miller) *Canadian white-footed mouse*

Tail 45% to 60% of total length, with a conspicuous tuft of hair at tip; ears and eyes large. *Adults never reddish brown above* (young bluish gray); belly hairs always snowy white at tips. (canadénsis; N. Lat., Canadian)

This mouse is an inhabitant of the forests of the Canadian and Hudsonian zones of eastern America. It is divisible into four subspecies, three of which occur within our limits.

SUBSPECIES OF PEROMYSCUS CANADENSIS

Adults very pale, grayish brown.............. P. canadensis abietorum
Adults not pale, grayish brown
  Adults yellowish brown.................. P. canadensis canadensis
  Adults dull brownish.................. P. canadensis nubiterrae

Peromyscus canadensis abietorum Bangs *Hudsonian white-footed mouse*

1896 Peromyscus canadensis abietorum Bangs, Proc. biolog. soc. Washington. 9 Mar. 1896. 10 : 49. (Lake Edward, Quebec)

Adults pale grayish brown above, never fuscous or yellowish. Total length, 190 ($7\frac{1}{2}$); tail vertebrae, 100 (4); hind foot, 21.5 ($\frac{13}{16}$). (abietórum; Lat., of the firs)

The Hudsonian white-footed mouse inhabits the spruce forests of Quebec, New Brunswick and Nova Scotia. It probably occurs in northern Maine.

Peromyscus canadensis canadensis Miller *Canadian white-footed mouse*

1893 Sitomys americanus canadensis Miller, Proc. biolog. soc. Washington. 20 June 1893. 8 : 55. (Peterboro, Madison co. N. Y.)

1896 Peromyscus canadensis Bangs, Proc. biolog. soc. Washington. 9 Mar. 1896. 10 : 49.

Adults dull yellowish brown above. Total length, 190 ($7\frac{5}{8}$); tail veterbrae, 100 (4); hind foot, 21.5 ($\frac{13}{16}$). (canadénsis; N. Lat., Canadian)

The Canadian white-footed mouse inhabits the Canadian zone and locally the cooler parts of the transition zone in the eastern United States and Canada. It is a characteristic forest animal.

Peromyscus canadensis nubiterrae Rhoads *Cloudland white-footed mouse*

1896 Peromyscus leucopus nubiterrae Rhoads, Proc. acad. nat. sci. Philadelphia. p. 187. (Summit of Roan mountain, N. C.)

1897 Peromyscus canadensis nubiterrae Rhoads, Proc. acad. nat. sci. Philadelphia. p. 213.

Adults dull brownish above. Total length, 170 (6¾); tail vertebrae, 86 (3½); hind foot 21.5 (1⅜). (nubitérrae; N. Lat., of Cloudland)

This form of the Canadian white-footed mouse is confined to the spruce forests of the high southern Alleghanies.

Peromyscus leucopus (Rafinesque) *Deer mouse*

1818 Musculus leucopus Rafinesque, Am. monthly magazine. 3: 446. (Kentucky)

1895 Peromyscus leucopus Thomas, Ann. and mag. nat. hist. Feb. 1895. ser. 6. 15:192.

Tail 40% to 45% of total length, with an inconspicuous tuft of hair at tip; ears and eyes moderate; *adults chestnut brown* above (young bluish gray); belly hairs always snowy white at tips. Total length, 170 (6¾); tail vertebrae, 75 (3); hind foot, 20 (1⅜). (Leúcopus; Gk., white foot)

The deer mouse is abundant throughout the upper austral and transition zones. The race occurring in the former is true leucopus, that of the transition zone has been separated as P. l. noveboracensis. (*See* Miller, Proc. Boston soc. nat. hist. 28: 22) The status of these forms is not well understood.

Peromyscus maniculatus (Wagner) *Labrador deer mouse*

1845 Hesperomys maniculatus Wagner, Wiegmann's Archiv für naturgesch. 11, 1: 148. (Moravian settlements of Labrador)

1898 Peromyscus maniculatus Bangs, American naturalist. July 1898. 32: 496.

Color about as in P. canadensis canadensis. Total length, 165 (6½); tail vertebrae, 74 (3); hind foot, 20 (¹³⁄₁₆). (maniculátus; Lat., gloved)

The Labrador white-footed mouse is probably confined to the wooded parts of the Hudsonian zone in Labrador. The species is very imperfectly known.

Genus **Neotoma** Say & Ord

1825 Neotoma Say & Ord. Jour. acad. nat. sci. Philadelphia. v. 9, pt 2, p. 346. Type Neotoma floridana Say & Ord.

Front teeth without grooves, narrow, compressed, much deeper than broad; grinding teeth rooted, the flat crown divided by enamel folds into loops and

triangles; form slender; tail long and hairy; eyes and ears large; fur soft. (Neótoma; Gk., new cutter)

The genus Neotoma is peculiar to America. It reaches its greatest development in Mexico and the southwestern United States, where 70 or more forms occur. One species only is found in the eastern United States north of the lower austral zone. This is a member of the restricted subgenus Neotoma, in which the tail is round.

Neotoma pennsylvanica Stone *Alleghany cave rat*

1894 Neotoma pennsylvanica Stone, Proc. acad. nat. sci. Philadelphia. p. 16. (South mountain, Cumberland co. Pa.)

Grayish above, white beneath, *tail furry, sharply bicolor.* Total length, 410 (16½); tail vertebrae, 85 (7⅝); hind foot, 42 (1$\frac{11}{16}$). (pennsylvánica; N. Lat., Pennsylvanian)

The Alleghany cave rat is common in caves and rocky woods throughout the Alleghanies. Its northern range extends to the lower Hudson valley. This is the common rat in Mammoth cave. Aside from the character of its teeth, the cave rat differs from the house rat in its larger eyes and ears, long soft fur and more hairy tail, *which is dark above and white below, the two colors sharply defined.*

Genus **Synaptomys** Baird

1857 Synaptomys Baird, Mamm. N. Am. p. 558. Type Synaptomys cooperi Baird

Face of each upper front tooth with a distinct longitudinal groove, grinding teeth without roots (prongs); skull small, not strongly angular; *claws small,* simple; tail moderate (about as long as hind foot) *covered with short hairs;* color always dark. (Synáptomys; Gk., connecting mouse)

The genus Synaptomys, containing the smallest and least specialized of the lemmings, has not been detected in the old world. It is generally distributed throughout boreal North America. Eight species are now recognized, four of which occur within our limits.

SPECIES OF SYNAPTOMYS

Mammae 6; crown of each lower cheek teeth with a small closed triangle of enamel on outer side (subgenus Synaptomys)
- Upper front teeth relatively broad and heavy .... S. cooperi
- Upper front teeth relatively narrow and light .. .. S. fatuus

Mammae 8; crown of lower cheek teeth without closed triangles of enamel on outer side (subgenus Mictomys)
- Total length, 115 (4½) .... S. innuitus
- Total length, 132 (5$\frac{3}{16}$).. S. sphagnicola

Synaptomys cooperi Baird *Cooper's lemming*

1857 Synaptomys cooperi Baird, Mamm. N. Am. p. 558. (Probably northern New Jersey or southern New York)

1896 Synaptomys cooperi Merriam, Proc. biolog. soc. Washington. 19 Mar. 1896. 10:58.

General appearance of a common meadow mouse, but tail very much shorter; color grizzled gray and yellowish brown thickly sprinkled with black; belly soiled whitish. Total length, 120 (4¾); tail vertebrae, 18 (11/16); hind foot, 18 (11/16). (cooperi; name from that of William Cooper)

Cooper's lemming is locally common in cool bogs and marshy places from Massachusetts to Virginia, west to Michigan and Indiana.

Synaptomys fatuus Bangs *Bangs's lemming*

1896 Synaptomys fatuus Bangs, Proc. biolog. soc. Washington. 9 Mar. 1896. 10: 47. (Lake Edward, Quebec)

1896 Synaptomys fatuus Merriam, Proc. biolog. soc. Washington. 19 Mar. 1896. 10:58

Like S. cooperi but with smaller front teeth and less heavily built anterior part of skull. Total length, 120 (4¾); tail vertebrae, 21 (⅞); hind foot, 18 (11/16). (fátuus; Lat., clumsy)

Bangs's lemming is common in bogs and wet woods of the Hudsonian zone and upper part of the Canadian zone from New Brunswick to the north shore of Lake Superior, south to New Hampshire. A single specimen has been recorded from the Catskills.

Synaptomys innuitus True *True's lemming*

1894 Mictomys innuitus True, Diagnoses of new North American mammals. 26 Ap. 1894. p. 3. Reprinted in Proc. U. S. nat. mus. 15 Nov. 1894. 17: 243. (Fort Chimo, Ungava, Labrador)

1896 Synaptomys innuitus Merriam, Proc. biolog. soc. Washington. 19 Mar. 1896. 10:61.

Like S. cooperi but smaller. Total length 115 (4½); tail vertebrae, 17 (11/16); hind foot, 17 (11/16); greatest length of skull, 19 (¾). (innúitus; N. Lat., Eskimo)

True's lemming is at present known from northern Labrador only (Fort Chimo and Hamilton inlet)

Synaptomys sphagnicola Preble *Preble's lemming*

1899 Synaptomys sphagnicola Preble, Proc. biolog. soc. Washington. 29 May 1899. 13: 43. (Fabyans, Coos co., New Hampshire)

Like S. cooperi but larger. Total length, 132 (5¾); tail vertebrae, 24 (15/16); hind foot, 20 (¾); greatest length of skull, 27 (1 1/16). (sphagnícola; N. Lat., an inhabitant of sphagnum)

Preble's lemming is at present known from the type specimen only, taken in the Canadian forests near the foot of Mt Washington, New Hampshire.

Genus **Dicrostonyx** Gloger

1844 Dicrostonyx Gloger, Gemeinn. hand- u. hilfsbuch d. naturgesch. 1: xxxi, 97. Type Mus hudsonius, Pallas.

Face of each upper front tooth smooth, grinding teeth without roots (prongs), *skull large, heavily angular; ears reduced to mere naked rims;* claws very large; *in winter apparently double;* tail very short with a long brush of stiff hairs; *fur turning white in winter.* (Dicróstonyx; Gk., fork claw)

The genus Dicrostonyx, containing the lemmings which turn white in winter, is circumpolar in distribution. One or more forms occur in northern Europe and Asia. The following species is found in Labrador.

Dicrostonyx hudsonius Pallas *Labrador lemming*

1778 Mus hudsonius Pallas, Nov. spec. quadr. glir. ord. p. 203.

1897 Dicrostonyx hudsonius Bangs, Proc. biolog. soc. Washington. 11: 237.

In summer about the color of a Maltese cat, slightly varied with rusty; a narrow black line down middle of back; in winter pure white. Total length, 150 (6); tail vertebrae, 21 ($\frac{13}{16}$); hind foot, 21 ($\frac{13}{16}$). (hudsónius; N. Lat., Hudsonian)

The range of the Labrador lemming is imperfectly known. The animal occurs on the barrens of northern Labrador, south at least to Hamilton inlet.

Genus **Fiber** Cuvier

1800 Fiber Cuvier, Leçons d'anat. comp. 1, tab. 1. (Described in Tab. elém. de l'hist. nat. des anim. 1798, p. 141) Type Castor zibethicus Linnaeus.

Front teeth without grooves, broader than deep; *grinding teeth with roots (prongs)*, body short and thick; tail long, *flattened laterally.* (Fíber; Lat., a beaver)

The genus Fiber containing the well known muskrat, is peculiar to America. Seven forms have been described, but their interrelationships are very imperfectly understood. Two species occur within our limits.

SPECIES OF FIBER

Upper lip yellowish brown, total length over 500 ($19\frac{3}{4}$)..... F. zibethicus
Upper lip white, total length under 500 ($19\frac{3}{4}$)............... F. obscurus

Fiber zibethicus Linnaeus *Muskrat*

Size usually large; hind foot generally about 80 ($3\frac{3}{16}$) color very variable; upper lip yellowish brown. (zibéthicus; Lat., a civet, in allusion to the musky odor)

The muskrat occurs throughout North America south into the lower austral zone. It is divisible into four or five races, two of which occur within our limits.

SUBSPECIES OF FIBER ZIBETHICUS

Hind foot about 80 ($3\frac{3}{16}$); color brown much suffused with yellowish and reddish....... F. zibethicus zibethicus

Hind foot about 73 ($2\frac{7}{8}$); color blackish brown, little suffused with yellowish and reddish.... .... F. zibethicus aquilonius

Fiber zibethicus zibethicus (Linnaeus) *Northern muskrat*

1766 [Castor] zibethicus Linnaeus, Systema naturae. ed. 12. 1: 79. (Eastern Canada)

1817 Fiber zibethicus Cuvier, Règne animal, 1: 192.

Rich dark brown above; sides and belly strongly tinged with rusty. Total length, 600 ($23\frac{1}{2}$); tail vertebrae, 267 ($10\frac{1}{2}$); hind foot, 80 ($3\frac{3}{16}$). (zibéthicus; Lat., a civet, in allusion to the musky odor)

The northern muskrat is abundant in marshes and on the borders of ponds and water courses throughout eastern North America, south at least into the upper austral zone. In Louisiana it is replaced by another race, F. z. rivalicius Bangs. In Labrador it gives way to the following form.

Fiber zibethicus aquilonius Bangs *Labrador muskrat*

1899 Fiber zibethicus aquilonius Bangs, Proc. New England zool. club. 28 Feb. 1899. 1:11.

Blackish brown above; sides and belly tinged with umber. Total length, 540 ($2\frac{1}{4}$); tail vertebrae, 240 ($9\frac{1}{2}$); hind foot, 73 ($2\frac{7}{8}$). (aquilónius; Lat., northern)

The Labrador muskrat is thus far known from Black bay, Labrador only. It probably ranges throughout the Hudsonian zone of Labrador.

Fiber obscurus Bangs *Newfoundland muskrat*

1894 Fiber obscurus Bangs, Proc. biolog. soc. Washington. 15 Sep. 1894. 9: 133. (Codroy, Newfoundland)

Blackish brown above; sides and belly light grayish brown tinged with fawn color; upper lip white. Total length, 180 (19); tail vertebrae, 210 ($8\frac{1}{4}$); hind foot, 70 ($2\frac{3}{4}$). (obscúrus; Lat., dark)

The Newfoundland muskrat is confined to the island of Newfoundland.

Genus Microtus Schrank

1798 Microtus Schrank, Fauna boica. 1: 72. Type Mus arvalis Pallas.

Front teeth without grooves, not compressed, broader than deep: *grinding teeth without roots*, (prongs); *bony palate not ending in a thin-edged shelf behind*; body stout and thick; tail short; ears just appearing above fur (*color seldom distinctly red*). (Micrótus; Gk., small ear)

The genus Microtus is distributed throughout the boreal and austral regions of the northern hemisphere. It probably contains one hundred or more species, seven of which occur within our limits.

SPECIES OF MICROTUS

Fur dense and mole-like; claws on front feet longest (subgenus Pitymys) .... M. pinetorum, p. 103

Fur not dense and mole-like; claws on hind feet longest (subgenus Microtus)

- Face or muzzle distinctly yellowish
  - Total length about 180 (6¾); muzzle patches pale .... M. terraenovae, p. 104
  - Total length about 165 (6¼); muzzle patches dark .... M. chrotorrhinus, p. 104
- Face or muzzle not distinctly yellowish
  - Total length often over 200 (8); color very pale .... M. breweri, p. 105
  - Total length seldom if ever reaching 200 (8); color dark
    - Teeth weak; front teeth protruding forward; the row of cheek teeth less than ¼ basal length of skull .... M. enixus, p. 105
    - Teeth strong; front teeth not protruding forward; the row of cheek teeth more than ¼ basal length of skull
      - Skull not very broad (the common field mouse of the eastern United States) .... M. pennsylvanicus, p. 105
      - Skull very broad (confined to Great Gull island off the eastern end of Long Island, New York) .... M. nesophilus, p. 107

Microtus pinetorum (Le Conte) *Pine mouse*

Fur dense velvety and mole-like, eyes and ears very small, *claws on front feet longest*; color of adults dull reddish brown; young slaty. (pinetórum; Lat., of the pines)

The pine mouse inhabits dry sandy soil (usually in thickets and open woods) in the austral zones and lower part of the transition zone of the United States from the Atlantic coast west to Missouri and Indian territory. It is divisible into four or more subspecies, one of which occurs within our limits.

Microtus pinetorum scalopsoides (Audubon & Bachman)

Northern pine mouse

1841 Arvicola scalopsoides Audubon & Bachman, Proc. acad. nat. sci. Philadelphia. Oct. 1841. 1:97. (Long Island, New York)

1896 Microtus pinetorum scalopsoides Batchelder, Proc. Boston soc. nat. hist. Oct. 1896. 27: 187.

1900 Microtus pinetorum scalopsoides Bailey North American fauna. June 1900. no. 17, p. 64.

Adults reddish brown, lighter than in the southeastern pine mouse (M. pinetorum pinetorum) of the lower austral zone. Total length, 125 (5); tail vertebrae, 22 (⅞); hind foot, 16 (⅝). (scalopsóides; Gk., mole-like)

The northern pine mouse inhabits the upper austral zone and lower part of the transition zone east of the Alleghanies. It generally occurs in colonies, which may be detected by the mole-like ridges thrown up by the animals.

Microtus terraenovae Bangs *Newfoundland vole*

1894 Arvicola terraenovae Bangs, Proc. biolog. soc. Washington. 27 July 1894. 9:129. (Codroy, Newfoundland)

1896 [Microtus] terraenovae Miller, North American fauna. 23 July 1896. no. 12, 66.

1900 Microtus terraenovae Bailey, North American fauna. 6 June 1900. no. 17, p. 25.

Above umber brown, slightly sprinkled with blackish hairs; below light gray; tail well haired, blackish above, light gray below; a pale dull tawny patch on each side of muzzle at roots of whiskers. Total length, 180 (6⅘); tail vertebrae, 50 (2); hind foot, 24 (1). (terraenóvae; N. Lat., of Newfoundland)

The Newfoundland vole is confined to the island of Newfoundland.

Microtus chrotorrhinus (Miller) *Rock vole*

Light brown above, thickly sprinkled with blackish hairs beneath; a conspicuous ochraceous patch on each side of muzzle; *hind foot about* 21 (⅞). (chrotorrhínus; Gk., color nose)

The rock vole inhabits heavy spruce woods and rock cavities in the Hudsonian zone of eastern North America. Two well marked subspecies are known, both of which occur within our limits.

SUBSPECIES OF MICROTUS CHROTORRHINUS

Muzzle patch dark tawny ochraceous, confined to extremity of muzzle	M. chrotorrhinus chrotorrhinus
Muzzle patch pale tawny ochraceous, suffusing whole face....	M. chrotorrhinus ravus

Microtus chrotorrhinus chrotorrhinus (Miller) *Southern rock vole*

1894 Arvicola chrotorrhinus Miller, Proc. Boston soc. nat. hist. 24 Mar. 1894. 26:190. (Mt Washington, New Hampshire)

1896 Microtus chrotorrhinus Bangs, Proc. biolog. soc. Washington. 9 Mar. 1896. 10:49.

1900 Microtus chrotorrhinus Bailey, North American fauna. 6 June 1900. no. 17, p. 58.

General color of upper parts umber brown; muzzle patches deep tawny ochraceous *strictly confined to sides of muzzle*. Total length, 165 (6½); tail vertebrae, 50 (2); hind foot, 20 (1$\frac{25}{32}$). (chrotorrhínus; Gk., color nose)

The southern rock vole is locally distributed in the Hudsonian zone and in cold situations in the Canadian zone of Quebec, New Brunswick, the White mountains, Adirondacks and Catskills.

Microtus chrotorrhinus ravus Bangs *Labrador rock vole*

1898 Microtus chrotorrhinus ravus Bangs, Proc. biolog. soc. Washington. 16 Nov. 1898. 12 : 188. (Black bay, Labrador)

1900 Microtus chrotorrhinus ravus Bailey, North American fauna. June 1900. No. 17, p. 59.

General color of upper parts light umber brown; muzzle patches pale tawny ochraceous *spreading over whole face.* Total length, 160 (6¼); tail vertebrae, 45 (1¾); hind foot, 22 (⅞). (rávus; Lat., yellow gray)

The Labrador rock vole is thus far known from Black bay, Labrador only.

Microtus breweri (Baird) *Muskeget island vole*

1857 Arvicola breweri Baird, Mamm. N. Am. p. 525. (Muskeget island, Massachusetts)

1896 Microtus breweri Miller, Proc. Boston soc. nat. hist. June 1896. 27 : 75.

1900 Microtus breweri Bailey, North American fauna. 6 June 1900. no. 17, p. 26.

Light gray, pure and whitish on belly, dull, tinged with wood brown and sprinkled with blackish hairs on back; *fur harsh and coarse.* Total length, 195 (7⅝); tail vertebrae, 48 (1⅞); hind foot, 24 (15/16). (bréweri; name from that of Thomas Mayo Brewer)

The Muskeget island vole is peculiar to the island of Muskeget, off Nantucket, Massachusetts.

Microtus enixus Bangs *Hamilton inlet vole*

1896 Microtus enixus Bangs, American naturalist. Dec. 1896. 30 : 1051. (Hamilton inlet Labrador)

1900 Microtus enixus Bailey, North American fauna. 6 June 1900. no. 17, p. 24.

Upper parts dark umber brown, much sprinkled with black hairs; under parts dark gray occasionally slightly washed with buffy, *teeth very lightly built, the front teeth slender and strongly projecting, the row of cheek teeth averaging less than ¼ basal length of skull.* Total length, 190 (7½); tail vertebrae, 60 (2⅜); hind foot, 22 (⅞). (enixus; Lat., zealous)

The Hamilton inlet vole is abundant throughout northern Labrador.

Microtus pennsylvanicus (Ord) *Field mouse*

Upper parts dark brown, much sprinkled with black; under parts gray, usually washed with buffy; *teeth strong, the front teeth heavy, not directed noticeably forward, the row of cheek teeth averaging more than ¼ basal length of skull;* skull with *long, narrow braincase.* (pennsylvánicus; N. Lat., Pennsylvanian)

This is the common field mouse abundant and well known throughout eastern North America from Labrador to North Carolina, and ranging

far to the westward. It is often erroneously called "mole" or "meadow mole". In the extensive territory which it inhabits the animal is differentiated into several geographic races, four of which occur within our limits.

SUBSPECIES OF MICROTUS PENNSYLVANICUS

Size large, total length of adult males often over 185 (7⅜)....	M. pennsylvanicus pennsylvanicus
Size medium or small, total length of adult males seldom if ever reaching 175 (6⅞)	
Total length of adults mostly under 140 (5½)	M. pennsylvanicus labradorius
Total length of adults mostly over 140 (5½)	
General color clear light brown..................	M. pennsylvanicus fontigenus
General color brown tinged with russet.............	M. pennsylvanicus acadicus

Microtus pennsylvanicus pennsylvanicus (Ord) *Common eastern field mouse*

1815 Mus pennsylvanica Ord, Guthrie's geography, Am. ed. 2. 2: 292. (Near Philadelphia Pa.)

1895 [Microtus] pennsylvanicus Rhoads, American naturalist. Oct. 1895. 24: 940

1900 Microtus pennsylvanicus Bailey, North American fauna. 6 June 1900. no. 17, p. 16.

General color above dark brown, usually tinged with tawny, under parts light gray often washed with buffy; *skull rather narrow;* fur not specially fine and soft. Total length, 180 (6¾); tail vertebrae, 50 (2); hind foot, 21 (1$\frac{13}{16}$)

The common eastern meadow mouse is abundant in fields and marshes throughout the eastern United States and southern Canada from well within the Canadian zone to the lower edge of the upper austral zone.

Microtus pennsylvanicus labradorius Bailey *Labrador field mouse*

1898 Microtus pennsylvanicus labradorius Bailey, Proc. biolog. soc. Washington. 30 Ap. 1898. 12: 88. (Fort Chimo, Ungava, Labrador)

1900 Microtus pennsylvanicus labradorius, Bailey, North American fauna. 6 June 1900. no. 17, p. 22.

Dark brown above, whitish below; *skull not very narrow.* Total length, 138 (5½); tail vertebrae, 38 (1½); hind foot, 19 (¾). (labradórius; N. Lat., Labradorean)

The Labrador field mouse inhabits the barrens of northern Labrador.

Microtus pennsylvanicus fontigenus (Bangs) *Northern field mouse*

1896 M i c r o t u s f o n t i g e n u s Bangs, Proc. biolog. soc. Washington. 9 Mar. 1896.p.48. (Lake Edward, Quebec)

1897 M i c r o t u s p e n n s y l v a n i c u s f o n t i g e n u s Miller, Proc. Boston soc. nat. hist. 30 Ap. 1897. 28 : 14.

1900 M i c r o t u s p e n n s y l v a n i c u s f o n t i g e n u s Bailey, North American fauna. 6 June 1900. no. 17, p. 21.

Upper parts clear sepia brown without tawny tinge; under parts light gray; skull narrow. Total length, 140 ($5\frac{1}{2}$); tail vertebrae, 40 ($1\frac{9}{16}$); hind foot, 20 ($\frac{3}{4}$). (f o n t í g e n u s; Lat., spring-born)

The northern field mouse inhabits fields, barrens and dry woods in the Hudsonian zone of eastern North America from Quebec to the north shore of Lake Superior.

Microtus pennsylvanicus acadicus Bangs *Acadian field mouse*

1897 M i c r o t u s p e n n s y l v a n i c u s a c a d i c u s Bangs, American naturalist. Mar. 1897. 30 : 239. (Digby, Nova Scotia)

1900 M i c r o t u s p e n n s y l v a n i c u s a c a d i c u s Bailey, North American fauna. 6 June 1900. no. 17, p. 19.

Upper parts varying from bister shaded with russet to almost clear russet; under parts dark gray; skull slender. Total length, 167 ($6\frac{9}{16}$); tail vertebrae, 45 ($1\frac{3}{4}$); hind foot, 20 ($\frac{3}{4}$). (a c á d i c u s; N. Lat., Acadian)

The Acadian meadow mouse is confined to the fields, fresh water marshes and forest glades of Nova Scotia.

Microtus nesophilus Bailey *Gull island mouse*

1898 M i c r o t u s i n s u l a r i s Bailey, Proc. biolog. soc. Washington. 12: 86. (Great Gull island, Long Island, N. Y.) not L e m m u s i n s u l a r i s Nilsson.

1899 M i c r o t u s n e s o p h i l u s Bailey, Science. n. s. 2 Dec. 1898, 8 : 782.

1900 M i c r o t u s n e s o p h i l u s Bailey, North American fauna. 6 June 1900. no. 17, p. 26.

Upper parts dark brown, slightly darker than in average specimens of M. p e n n s y l v a n i c u s; under parts dusky, washed with cinnamon; teeth as in M. p e n n s y l v a n i c u s; *skull with short broad braincase.* Tail vertebrae, 29 ($1\frac{1}{8}$); hind foot, 20 ($\frac{3}{4}$). (n e s ó p h i l u s ; Gk., island lover)

The Gull island mouse is confined to Great Gull island and Little Gul island, off the eastern extremity of Long Island, New York. The species is probably extinct.

Genus **Phenacomys** Merriam

1889 Phenacomys Merriam, North American fauna. 30 Oct. 1889. no. 2, p. 28. Type Phenacomys intermedius Merriam.

Front teeth without grooves, broader than deep; *grinding teeth rooted* (pronged) *in adults, large and heavy; bony palate not ending in a thin-edged shelf behind;* body short and thick; tail short; ears just appearing above fur; color never distinctly red. (Phenácomys; Gk., impostor mouse)

So far as at present known the genus Phenacomys is peculiar to North America. Six species are recognized, two of which occur within our limits.

SPECIES OF PHENACOMYS

Total length about 150 ($5\frac{7}{8}$); skull with a deep groove between eye sockets.. P. celatus
Total length about 130 ($5\frac{1}{8}$); skull without distinct groove between eye sockets.. P. latimanus

Phenacomys celatus Merriam *Large yellow-faced phenacomys*

1889 Phenacomys celatus Merriam, North American fauna. 30 Oct. 1889. no. 2, p. 33. (Godbout, Quebec, Canada)

1897 Phenacomys ungava Miller, Proc. biolog. soc. Washington. 21 Ap. 1897. 11:84.

Yellowish brown above; whitish below; *face suffused with reddish.* Total length, 150 ($5\frac{7}{8}$); tail vertebrae, 35 ($1\frac{3}{8}$); hind foot, 20 ($\frac{13}{16}$). (celátus; Lat., secret)

The large yellow-faced phenacomys ranges throughout the Hudsonian zone in Labrador and eastern Canada, south to southeastern Quebec. It has not yet been taken in Nova Scotia or the United States.

Phenacomys latimanus Merriam *Small yellow-faced phenacomys*

1889 Phenacomys latimanus Merriam, North American fauna. 30 Oct. 1889. no. 2, p. 34. (Fort Chimo, Ungava, Labrador)

1897 Phenacomys latimanus Miller, Proc. biolog. soc. Washington. 21 Ap. 1897. 11: 83.

Color as in P. celatus. Total length, 130 ($5\frac{1}{8}$); tail vertebrae, 30 ($1\frac{1}{8}$); hind foot, 18 ($\frac{11}{16}$). (latímanus; Lat., broad hand)

The small yellow-faced phenacomys ranges from western Labrador to the north shore of Lake Superior. It is apparently confined to barrens and open places, seldom if ever entering the dense forests inhabited by the red-backed mice.

Genus Evotomys Coues

1874 Evotomys Coues, Proc. acad. nat. sci. Philadelphia. p. 186. Type Mus rutilus Pallas.

Front teeth without grooves, broader than deep; *grinding teeth rooted* (pronged) *in adults, small and weak; bony palate ending in thin-edged shelf behind;* body short and thick; tail short, ears usually just appearing above fur; *color of back usually distinctly red.* (Evótomys; Gk., well-eared mouse)

The genus Evotomys which occurs throughout the cooler part of the northern hemisphere is represented in America by about 25 forms. Five species occur within our limits.

SPECIES OF EVOTOMYS

Red area on back fading insensibly into color of sides
- Ears small, completely covered by the surrounding fur; teeth small .... E. ungava
- Ears large, appearing conspicuously above surrounding fur; teeth very heavy .... E. carolinensis

Red area on back sharply defined from color of sides
- Tail considerably more than twice length of hind foot... E. proteus
- Tail scarcely more than twice length of hind foot, or less
  - Hind foot about 19 ($\frac{3}{4}$); skull small; teeth light ...... E. gapperi
  - Hind foot about 21 ($\frac{13}{16}$); skull large; teeth heavy..... E. rhoadsi

Evotomys ungava Bailey *Ungava red-backed mouse*

1897 Evotomys ungava Bailey, Proc. biolog. soc. Washington. 13 May 1897. 11: 130. (Fort Chimo, Ungava, Labrador)

Ears very small, not projecting above fur; back dull brownish chestnut, fading insensibly into buffy gray of sides; tail about twice as long as hind foot. Total length, 135 ($5\frac{1}{4}$); tail vertebrae, 40 ($1\frac{9}{16}$); hind foot, 19 ($\frac{3}{4}$). (ungáva; N. Lat., Ungava)

The Ungava red-backed mouse is known from Ungava, Labrador only.

Evotomys carolinensis Merriam *Carolina red-backed mouse*

1888 Evotomys carolinensis Merriam, Amer. jour. sci. and arts. Dec. 1888. 36: 460. (Roan mountain, North Carolina)

1897 Evotomys carolinensis Bailey, Proc. biolog. soc. Washington. 13 May 1897. 11: 130.

Ears large, projecting conspicuously above fur; *back dark chestnut fading insensibly into bister of sides;* tail about twice as long as hind foot. Total length, 150 ($5\frac{7}{8}$); tail vertebrae, 45 ($1\frac{3}{4}$); hind foot, 21 ($\frac{13}{16}$). (Carolinénsis; N. Lat., Carolinian)

The Carolina red-backed mouse is confined to the boreal mountain forests of the southern Alleghanies (Tennessee, North Carolina, West Virginia and Virginia).

Evotomys proteus Bangs *Variable red-backed mouse*

1897 Evotomys proteus Bangs, Proc. biolog. soc. Washington. 13 May 1897. 11:137. (Hamilton inlet, Labrador)

Ears large, projecting conspicuously above fur, *back varying from slate color and dark sepia to dull yellowish and bright chestnut*, usually sharply marked off from gray of sides; *tail much more than twice as long as hind foot.* Total length, 160 (6¼); tail vertebrae, 50 (2); hind foot, 21 (13/16). (próteus; Lat., a many formed sea god)

The variable red-backed mouse has been taken in the stunted spruce forest at Hamilton inlet, Labrador, only.

Evotomys gapperi (Vigors) *Common red-backed mouse*

Ears large, projecting conspicuously above fur; *color of back sharply defined* from that of sides, tail about twice as long as hind foot. (gápperi; name from that of Dr Gapper)

The common red-backed mouse occurs in the forests of the boreal zone and cooler parts of the transition zone throughout the greater part of the northern United States and southern Canada. It is divisible into six or more well marked geographic races, two of which are found within our limits. In the northern part of its range brown individuals (E. fuscodorsalis Allen) are of frequent occurrence.

SUBSPECIES OF EVOTOMYS GAPPERI

Back bright chestnut sprinkled with black hairs. E. gapperi gapperi
Back dull rusty rufous without sprinkling of black hairs..E. gapperi ochraceus

Evotomys gapperi gapperi (Vigors) *Eastern red-backed mouse*

1830 Arvicola gapperi Vigors, Zool. jour. 5:204. (Region between York and Lake Simcoe, Ontario, Canada)

1891 Evotomys gapperi Merriam, North American fauna. 30 July 1891. no. 5, p. 119.

1897 Evotomys gapperi Bailey, Proc. biolog. soc. Washington. 13 May 1897. 11: 122.

Back bright chestnut, sprinkled with blackish hairs; sides bright buffy ochraceous; belly gray washed with pale buff. Total length, 140 (5½); tail vertebrae, 40 (1 9/16); hind foot, 18 (¾). (gápperi; name from that of Dr Gapper)

The eastern red-backed mouse is abundant in the forests of the boreal zone and cooler parts of the transition zone from Quebec to Pennsylvania and from the Atlantic coast to Dakota.

Evotomys gapperi ochraceus Miller, *Mount Washington red-backed mouse*

1894 Evotomys gapperi ochraceus Miller, Proc. Boston soc. nat. hist. 24 Mar. 1894. 26: 193. (Mt Washington, New Hampshire)

1897 Evotomys gapperi ochraceus Bailey, Proc. biolog. soc. Washington. 13 May 1897. 11: 124.

Back pale, dull, rusty rufous, without sprinkling of blackish hairs, sides buffy clay color; belly dirty whitish. Total length, 150 (5⅞); tail vertebrae, 40 (1$\frac{9}{16}$); hind foot, 19 (¾). (ochráceus; Lat., ochraceous)

The Mt Washington red-backed mouse is so far as known confined to the upper boreal zone of Mt Washington, New Hampshire.

Evotomys rhoadsi (Stone) *New Jersey red-backed mouse*

1893 Evotomys gapperi rhoadsi Stone, American naturalist. Jan. 1893. 27: 54. (Mays Landing N. J.)

1897 Evotomys gapperi rhoadsi Bailey, Proc. biolog. soc. Washington. 13 May 1897. 11: 125.

Ears large, projecting conspicuously above fur; back dark chestnut, *sharply marked off* from buffy gray of sides; *skull and teeth much heavier than in* E. gapperi, in this respect resembling E. carolinensis. Total length, 140 (5½); tail vertebrae, 40 (1$\frac{9}{16}$); hind foot, 21 ($\frac{13}{16}$). (rhoádsi; name from that of Samuel N. Rhoads)

The New Jersey red-backed mouse has thus far been found in the cool bogs of southern New Jersey and southern New York only.

Family **Dipodidae** *Jerboas and jumping mice*

Front teeth two, compressed (in our genera *each with a deep longitudinal groove on front face*); cheek teeth in upper jaw usually four on each side (three in Napaeozapus); skull with a conspicuous aperture opening forward in front of the eye socket; tail and hind legs elongated for jumping. (Dipódidae; genus, Dipus)

The family Dipodidae is widely distributed through North America, Asia, Africa and eastern and northern Europe. Half a dozen or more old world genera are now recognized, while only two are found in America. The latter form the subfamily Zapodínae.

GENERA OF DIPODIDAE

A small, probably useless tooth in front of first well developed grinder in upper jaw .... Zapus

No small tooth in front of first well developed grinder in upper jaw .... Napaeozapus

Genus Zapus Coues

1873 Zapus Coues, Bull. U. S. geolog. surv. terr. ser. 2, no. 5, p. 253. Type Dipus hudsonius Zimmermann.

Teeth 18; tail considerably longer than head and body; hind foot greatly elongated, between one half and one third as long as head and body. (Zápus; Gk., much foot)

The genus Zapus reaches its greatest development in boreal North America. Several species are known, all North American but one, which occurs in western China. Only one is found within our limits.

Zapus hudsonius (Zimmermann) *Meadow jumping mouse*

Back and sides yellowish brown, the former heavily, the latter lightly sprinkled with darker hairs; belly white, usually *strongly tinged with yellowish; tail brown to extreme tip.* (hudsónius; N. Lat., Hudsonian)

The meadow jumping mouse is common in meadows, old fields and open woods throughout eastern North America south to the northern edge of the upper austral zone. It is divisible into several races, three of which occur within our limits.

SUBSPECIES OF ZAPUS HUDSONIUS

Total length under 200 (8); hind foot less than 30 ($1\frac{3}{16}$)..Z hudsonius americanus

Total length over 215 ($8\frac{1}{2}$); hind foot more than 30 (1)

Total length about 220 ($8\frac{5}{8}$).......................... Z. hudsonius hudsonius

Total length about 230 ($9\frac{1}{8}$).......................... Z. hudsonius ladas

Zapus hudsonius americanus (Barton) *Southern meadow jumping mouse*

1799 Meriones americanus Barton, Trans. Am. philos. soc. 4:115. (Philadelphia Pa.)

1899 Zapus hudsonius americanus Batchelder, Bull. New England zool. club. 8 Feb. 1899. 1: 6.

1899 Zapus hudsonius americanus Preble, North American fauna. 8 Aug. 1899. no. 15, p. 19.

Back dusky brown faintly tinged with reddish buff, sides reddish buff, very slightly grizzled. Total length, 190 ($7\frac{1}{2}$); tail vertebrae, 115 ($4\frac{1}{2}$); hind foot, 18 ($1\frac{1}{8}$). (americánus; N. Lat., American)

The southern meadow jumping mouse occurs throughout the upper austral zone of the eastern United States from North Carolina northward. In the transition zone it intergrades with the next race.

Zapus hudsonius hudsonius (Zimmermann) *Northern meadow jumping mouse*

1780 Dipus hudsonius Zimmermann, Geogr. Gesch. 2:358. (Hudson bay)
1873 Zapus hudsonius Coues, Bull. U. S. geolog. surv. terr. ser. 2. no. 5, p. 254.
1899 Zapus hudsonius Preble, North American fauna. 8 Aug. 1899. no. 15, p. 15.

Back yellowish brown; sides light grayish buff, slightly sprinkled with black. Total length, 220 (8⅔); tail vertebrae, 130 (5⅛); hind foot, 31 (1$\frac{3}{16}$). (hudsónius; N. Lat., Hudsonian)

The northern meadow jumping mouse occurs throughout the Canadian zone and lower part of the Hudsonian zone of eastern North America except in the area occupied by the following form.

Zapus hudsonius ladas Bangs *Labrador meadow jumping mouse*

1899 Zapus hudsonius ladas Bangs, Proc. New England zool. club. 28 Feb. 1899. 1:10. (Hamilton inlet, Labrador)
1899 Zapus hudsonius ladas Preble, North American fauna. 8 Aug. 1899. no. 15, p. 17.

Back blackish; sides tawny ochraceous, conspicuously sprinkled with black. Total length, 230 (9⅛); tail vertebrae, 145 (5¾); hind foot, 32 (1¼). (ládas; from name of a famous runner of Alexander the Great)

The Labrador meadow jumping mouse is at present known from eastern Labrador only.

Genus **Napaeozapus** Preble

1899 Napaeozapus Preble, North American fauna. 8 Aug. 1899. no. 15, p. 33. Type Zapus insignis Miller.

Teeth 16; otherwise as in Zapus. (Napaeozápus; Gk., woodland Zapus)

The genus Napaeozapus is peculiar to eastern North America, where it is represented by one species only.

Napaeozapus insignis Miller *Woodland jumping mouse*

Back and sides yellowish brown, the former heavily, the latter scarcely, sprinkled with black; belly always pure white; *tail tipped with white.* (insígnis; Lat., distinguished)

The woodland jumping mouse is abundant in heavy woods (chiefly near watercourses) throughout the Hudsonian and Canadian zones of eastern North America. It also occurs sparingly in isolated cool localities in the upper edge of the transition zone. It is divisible into three races.

SUBSPECIES OF NAPAEOZAPUS INSIGNIS

Total length about 250 (9⅞); hind foot about 33 (1$\frac{5}{16}$) .... N. insignis abietorum

Total length about 225 (8⅞); hind foot about 30 (1$\frac{3}{16}$)

Colors bright; hind foot usually more than 30 (1$\frac{3}{16}$) .... N. insignis insignis

Colors dull; hind foot usually less than 30 (1$\frac{3}{16}$)..N. insignis roanensis

Napaeozapus insignis abietorum (Preble) *Hudsonian woodland jumping mouse*

1899 Zapus (Napaeozapus) insignis abietorum Preble, North American fauna. 8 Aug. 1899. no. 15, p. 36. (North shore of Lake Superior)

Size very large; skull broad between eye sockets. Total length, 250 (9⅞); tail vertebrae, 160 (6$\frac{5}{16}$). (abietórum; Lat., of the firs)

The northern woodland jumping mouse is confined to the Hudsonian zone of eastern Canada.

Napaeozapus insignis insignis Miller *Northern woodland jumping mouse*

1891 Zapus insignis Miller, American naturalist. Aug. 1891. 25:472. (Restigouche river, New Brunswick)

1899 Zapus (Napaeozapus) insignis Preble, North American fauna. 8 Aug. 1899. no. 15, p. 33.

Size medium; skull narrow between eye sockets; color bright. Total length, 235 (9¼); tail vertebrae, 145 (5¾); hind foot, 31 (1$\frac{7}{32}$). (insígnis; Lat., distinguished)

The northern woodland jumping mouse is abundant throughout the Canadian forests of the eastern United States and Canada.

Napaeozapus insignis roanensis (Preble) *Mountain woodland jumping mouse*

1899 Zapus (Napaeozapus) insignis roanensis Preble, North American fauna. 8 Aug. 1899. no. 15, p. 35. (Roan mountain, N. C.)

Size small; skull narrow between eye sockets; colors dull. Total length, 220 (8¾); tail vertebrae, 130 (5⅛); hind foot, 30 (1$\frac{3}{16}$). (roanénsis; N. Lat., inhabiting Roan mountain)

The mountain woodland jumping mouse is at present known from the evergreen forests of Roan mountain only. It probably occurs in the Canadian zone throughout the southern Alleghanies.

Family **Erethizontidae** *New world porcupines*

Cheek teeth rooted; no thumb; *fur mixed with long stiff quills.* (Erethizóntidae; genus Erethizon)

The new world porcupines are represented by three genera, two of which are tropical. The third occurs throughout the wooded portion of boreal North America.

Genus **Erethizon** F. Cuvier

1825 Erethizon F. Cuvier, Dents des mammifères, p. 256. Type Hystrix dorsatus Linnaeus

Tail short, not prehensile; toes four in front, five behind. (Erethízon; Gk., to irritate)

The genus Erethizon is confined to the northern parts of North America. Two species are known, one of which occurs within our limits.

Erethizon dorsatus (Linnaeus) *Canada porcupine, "hedgehog"*

1758 Hystrix dorsatus Linnaeus, Systema naturae. ed. 10. 1:57. (Canada)
1822 Erethizon dorsatus F. Cuvier, Mém. du muséum d'hist. nat. Paris. 9:432.

Blackish; quills whitish tipped. Total length, 700 (28); tail vertebrae, 200 (8) hind foot, 90 ($3\frac{1}{2}$). (dorsatus; Lat., large-backed)

The Canada porcupine occurs throughout the Canadian zone of northeastern North America wherever are still found sufficiently extensive tracts of unbroken forest. It is chiefly arboreal in habits. The true hedgehogs are very different animals (insectivores) confined to the old world.

Family **Leporidae** *Hares*

Upper front teeth four, *a large pair in front and a small pair immediately behind;* front legs short; hind legs elongated for jumping; tail very short or rudimentary. (Lepóridae; genus *Lepus*)

The family Leporidae, though nearly universally distributed outside of Australia and the neighboring islands, contains only two genera, one of which is peculiar to the high mountains of southern Mexico.

Genus **Lepus** Linnaeus

1758 Lepus Linnaeus, Systema naturae. ed. 10. 1:57. Type Lepus timidus, Linnaeus.

Tail well developed; ears long and narrow; hind legs very long. (Lépus; Lat., a hare)

The genus Lepus, the range of which is coincident with that of the family, probably contains more than one hundred species. Four of these occur in northeastern North America.

SPECIES OF LEPUS

Size small; hind foot under 115 ($4\frac{1}{2}$); fur never turning white in winter (cottontails, subgenus Sylvilagus) L. floridanus

Size medium or large; hind foot 125 (5) to 165 ($6\frac{1}{2}$); fur in American species generally turning white in winter (hares, subgenus Lepus)

Total length usually less than 500 ($19\frac{3}{4}$); fur usually but not always turning white in winter (varying hares).. L. americanus

Total length about 600 ($23\frac{1}{2}$) or more; fur always turning white in winter (arctic hares)

Hind foot, 145 ($5\frac{3}{4}$); ear from crown, 100 (4)........... L. labradorius

Hind foot, 165 ($6\frac{1}{2}$); ear from crown, 85 ($3\frac{3}{8}$).......... L. bangsi

Lepus labradorius Miller *Labrador arctic hare*

1896 Lepus arcticus bangsi Rhoads, Proc. acad. nat. sci. Philadelphia, p. 365. (part)

1899 Lepus labradorius Miller, Proc. biolog. soc. Washington. (Fort Chimo, Ungava, Labrador)

General color in summer light brown, turning to dusky bluish gray on sides and to white on under parts; in winter pure white; ears always tipped with black; tail snowy white. Total length, 600 ($23\frac{1}{2}$); tail vertebrae, 55 ($2\frac{3}{16}$); *hind foot, 145* (*$5\frac{3}{4}$*)*; ear from crown, 100* (4). (labradórius; N. Lat., Labradorean)

The Labrador arctic hare is confined to the barren region of northern Labrador, where it is abundant. Its range extends as far south as Hamilton inlet.

Lepus bangsi (Rhoads) *Newfoundland arctic hare*

1896 Lepus arcticus bangsi Rhoads, American naturalist. Mar. 1896. 30: 253. (part) (Codroy Newfoundland)

1896 Lepus arcticus bangsi Rhoads, Proc. acad. nat. sci. Philadelphia. p. 365. (part)

General color in summer light brown, turning to dusky bluish gray on sides and to white on under parts, in winter pure white; ears always tipped with black; tail snowy white. Total length, 600 ($23\frac{1}{2}$); tail vertebrae, 65 ($2\frac{5}{8}$) *hind foot, 165* (*$6\frac{1}{2}$*); *ear from crown, 85* (*$3\frac{5}{8}$*). (bángsi; name from that of Outram Bangs)

The Newfoundland arctic hare is confined to the island of Newfoundland.

Lepus americanus Erxleben *American varying hare*

Size medium (much less than that of the western jack rabbits, and northern arctic hares); fur usually undergoing marked periodic changes, from brown to white in autumn and from white to brown in spring; *tail* (in dark pelage), *dull yellowish or whitish beneath.* (americánus; N. Lat., American)

The American varying hare is a wide ranging species divisible into numerous geographic races. Three of these occur in northeastern North America.

SUBSPECIES OF LEPUS AMERICANUS

Hind foot small, about 127 (5) in length... L. americanus struthopus
Hind foot large, about 140 (5½) in length
General color (in summer coat) light yellowish brown or drab; ears conspicuously rimmed with white............ L. americanus americanus
General color (in summer coat) russet or rusty; ears inconspicuously rimmed with white.............................. L. americanus virginianus

Lepus americanus struthopus Bangs *Nova Scotian hare*

1898 Lepus americanus struthopus Bangs, Proc. biolog. soc. Washington. 24 Mar. 1898. 12:81. (Digby N. S.)

Hind foot small; color in summer dull tawny brown, (varying from raw umber to bister); black-tipped hairs on back not numerous; ears dusky or black at tip; *borders of ears yellowish brown.* Length, 470 (18½); tail, 50 (2); *hind foot,* 127 (5). (strúthopus; Lat., small-footed)

The Nova Scotian hare, as its name implies, is confined to the province of Nova Scotia, where it is exceedingly abundant.

Lepus americanus americanus Erxleben *Northern varying hare*

1777 Lepus americanus Erxleben, Syst. regn. anim. 1:330.

1898 Lepus americanus americanus Bangs, Proc. biolog. soc. Washington. 12:78.

Hind foot large; color in summer pale tawny brown, (varying from hair brown and drab to tawny clay color); black-tipped hairs on back numerous; ears dusky at tips; *borders of ears conspicuously white.* Length, 470 (18½); *tail,* 38 (1½); *hind foot,* 150 (6). (americánus; N. Lat., American)

The northern varying hare occupies the wooded portions of Labrador. Its southern limit is not definitely known; but the animal does not reach the northern border of the United States.

Lepus americanus virginianus (Harlan) *Southern varying hare*

1825 Lepus virginianus Harlan, Fauna Americana, p. 196. (Blue mountains of Pennsylvania)

1877 [Lepus americanus] var. virginianus Allen, Monogr. N. Am. rodentia, p. 307.

1898 Lepus americanus virginianus Bangs, Proc. biolog. soc. Washington. 12:79.

Hind foot large; color in summer bright rusty brown, (varying from russet to deep rust color); black-tipped hairs on back numerous; ears dusky at tip; borders of ears very inconspicuously whitish. Length, 485 (19); tail, 50 (2); hind foot, 140 (5½). (virginiánus; N. Lat., Virginian)

The southern varying hare inhabits the Canadian zone and cool, damp situations in the transition zone of the eastern United States and southeastern Canada. At the southern extremity of its range the animal does not assume the white coat in winter.

Lepus floridanus Allen *Cottontail*

Size small; fur always dark; feet stout, well furred; *tail conspicuously snowy white beneath.* (floridánus; N. Lat., Floridian)

The cottontail like the varying hare is a wide ranging species. It is divisible into even more local races than its larger relative. Only three of these subspecies occur within our limits. The typical form, Lepus floridanus floridanus, is confined to the peninsula of Florida.

SUBSPECIES OF LEPUS FLORIDANUS

General color bright yellowish brown with a strong admixture of black; a distinct black spot between ears .... L. floridanus transitionalis

General color pale yellowish brown with very faint admixture of black; no black spot between ears

Rump noticeably paler than back; hind foot often over 100 (4) .... L. floridanus mearnsi

Rump not noticeably paler than back; hind foot generally under 100 (4) .... L. floridanus mallurus

Lepus floridanus transitionalis (Bangs) *Northeastern cottontail*

1895 Lepus sylvaticus transitionalis Bangs, Proc. Boston soc. nat. hist. 1894. 26: 405. 31 Jan. 1895 (Liberty Hill Ct.)

1899 Lepus floridanus transitionalis Allen, Bull. Am. mus. nat. hist. 4 Mar. 1899. 12: 13.

Hair long, full and silky; *color bright,* chiefly russet, wood brown and hazel; back heavily sprinkled with black-tipped hairs; *rump not noticeably paler than back, a black spot between ears*; ears thickly furred and with decided black margin on outer edge. Length, 430 (17); tail, 55 ($2\frac{1}{8}$); hind foot, 95 ($3\frac{3}{4}$). (transitionális; N. Lat., pertaining to the transition zone)

The northeastern cottontail inhabits the transition zone of southern New England and eastern New York.

Lepus floridanus mearnsi Allen *Eastern prairie cottontail*

1894 Lepus sylvaticus mearnsi Allen, Bull. Am. mus. nat. hist. 6: 171. (Fort Snelling Minn.)

1895 Lepus sylvaticus mearnsi Bangs, Proc. Boston soc. nat. hist. 26: 406.

1899 Lepus floridanus mearnsi Allen, Bull. Am. mus. nat. hist. 4 Mar. 1899. 12:13.

Hair long, full and soft; *color pale,* chiefly wood brown and gray; back not heavily sprinkled with black-tipped hairs; *rump very noticeably paler than back; no black spots between ears;* ears thinly furred and without distinct black margins. Length, 475 (18¾); tail, 65 (2½); hind foot, 100 (4). (meárnsi; name from that of Edgar A. Mearns)

The eastern prairie cottontail is a member of the eastern prairie fauna of the transition and upper austral zones. It would therefore not come within the scope of the present paper had it not recently extended its range as far as Toronto, Ontario and central New York.

Lepus floridanus mallurus (Thomas) *Southeastern cottontail*

1837 Lepus sylvaticus Bachman, Jour. acad. nat. sci. Philadelphia. 7: 403. Eastern United States. (Not Lepus borealis sylvaticus Nilsson, 1832)

1895 Lepus sylvaticus Bangs, Proc. Boston soc. nat. hist. 26: 405.

1898 Lepus nuttalli mallurus Thomas, Ann. and mag. nat. hist. ser. 7, 2: 320. (Raleigh N. C.)

1899 Lepus floridanus mallurus Allen, Bull. Am. mus. nat. hist. 4 Mar. 1899. 12: 13.

Hair short and coarse; *color dull,* chiefly wood brown and cinnamon; back not heavily sprinkled with black-tipped hairs; rump not noticeably paler than back; *no black spot between ears;* ears rather thinly furred, and without distinct dark margins. Length, 430 (17); tail, 55 (2⅛); hind foot, 95 (3¾). (mallúrus; Gk., wool tail)

The southeastern cottontail is abundant through the austral zones of the eastern United States. Its northern limit reaches the lower Hudson valley.

Order Ferae *Flesh-eaters or carnivores*

Canine teeth well developed; cheek teeth formed for cutting; front teeth small, in a row between the canines; toes provided with claws; brain large, well developed; species occurring within our limits large or medium sized, the smallest (weasels) about 300 (1 ft) in length; eyes well developed; fur not modified for an underground life. (Férae; Lat., wild beasts)

The order Ferae, containing the cats, dogs, bears, weasels, racoons, etc., is distinguished among the groups of mammals occurring in North America by the high development of the teeth for flesh-cutting. The order is very generally distributed in the new world and in the old world outside of Australia. It contains about a dozen families, six of which are found in northeastern North America.

FAMILIES OF FERAE

Limbs so highly modified for swimming as to be practically useless for walking (Pinnipedia; seals and their allies)
- Hind feet capable of turning forward under the body; a large tusk on each side of upper jaw (walruses).. Rosmaridae, p. 120
- Hind feet permanently directed backward; no tusks (seals).. Phocidae, p. 121

Limbs normal (Fissipedia; the true carnivores)
- Hind foot with four toes
  - Claws retractile into a sheath; muzzle broad and short; teeth not more than 30 (cats)........... Felidae, p. 123
  - Claws not retractile; muzzle narrow and long; teeth 42 (dogs)................................ Canidae, p. 126
- Hind foot with five toes
  - Entire sole not applied to ground in walking (weasels, otters, martins etc.)............... Mustelidae, p. 129
  - Entire sole applied to ground in walking
    - Size small or medium; tail well developed; teeth 36 to 40 (racoons, etc.)....................... Procyonidae, p. 137
    - Size very large, tail rudimentary; teeth 42 (bears) Ursidae, p. 138

Family **Rosmaridae** *Walruses*

Hind feet capable of turning forward under body; no external ears; *a large tusk growing downward from each side of upper jaw.* (Rosmáridae; genus Rosmarus)

The family Rosmaridae contains the one genus Rosmarus.

Genus **Rosmarus** Scopoli

1777 Rosmarus Scopoli, Introd. hist. nat. p. 490. Type Trichechus rosmarus Linnaeus.

Characters of the family. (Rosmárus; an old name for the walrus first used by Olaus Magnus in the 16th century)

The genus Rosmarus is represented by two species, one each in the north Atlantic and north Pacific.

Rosmarus rosmarus (Linnaeus) *Atlantic walrus*

1766 Trichechus rosmarus Linnaeus, Systema naturae. ed. 12. 1:49. (North Atlantic ocean)

1880 Odobaenus rosmarus Allen, History of North American pinnipeds, p. 23.

1894 Rosmarus rosmarus Rhoads, American naturalist. 28:523.

Characters as above; bristly nose pad narrow. (rosmárus; an old name)

The Atlantic walrus, within our limits is now restricted to northern Labrador; its range formerly extended much farther south.

Family **Phocidae** *Earless seals*

Hind feet directed *permanently backward;* no etxernal ears; no tusks. (Phócidae; genus Phoca)

The family Phocidae contains a dozen or more genera distributed on practically all sea coasts. Four occur in North America, all of which are represented within our limits.

GENERA OF PHOCIDAE

Teeth 30; snout of male developed into a conspicuous "hood" (subfamily Cystophorinae)........................ Cystophora
Teeth 34; snout not specially developed (subfamily Phocinae)
  Braincase forming less than one third of length of skull.... Halichoerus
  Braincase forming nearly one half of length of skull
    Cheek teeth large and strong; forehead high, arched.............. Phoca
    Cheek teeth small and weak; forehead low, flat........... Erignathus

Genus **Cystophora** Nilsson

1820 Cystophora Nilsson, Skand. fauna. 1:382. Type Cystophora borealis Nilsson=Phoca cristata Erxleben.

Teeth 30 (*only two front teeth in lower jaw*); muzzle elongated, that of male capable of inflation. (Cystóphora; Gk., bladder-bearer)

The genus Cystophora is peculiar to the coasts and islands of the North Atlantic. Only one species is known.

Cystophora cristata (Erxleben) *Hooded seal*

1777 [Phoca] cristata Erxleben, Syst. regn. anim. 1:590. (Greenland)
1837 Cystophora cristata Nilsson, Kongl. Vet. akad. Handl. Stockholm.
1880 Cystophora cristata Allen, History of North American pinnipeds, p. 724.
1884 Cystophora cristata Merriam, Science. 5 Dec. 1884. 4:514.

Bluish black, lighter on sides and belly; back thickly sprinkled with irregular whitish spots. Total length 2450 (7 ft) to 2800 (8 ft). (cristáta; Lat., crested)

The hooded seal occurs on the northern coasts of western Europe and eastern North America. In the latter country its southward range extends about to Nova Scotia, though stragglers have been taken as far south as Long Island.

Genus **Halichoerus** Nilsson

1820 Halichoerus Nilsson, Faun. Skand. 1:377. Type Halichoerus griseus Nilsson=Phoca grypus Fabricius.

Teeth 34 *(four front teeth in lower jaw)*; braincase very small, forming less than one third length of skull. (Halichoérus; Gk., sea pig)

The genus Halichoerus is peculiar to the coasts and islands of the North Atlantic. Only one species is known.

Halichoerus grypus (Fabricius) *Gray seal*

1791 Phoca grypus Fabricius, Skriv. af Naturh. Selsk. 1:167.

1837 Halichoerus grypus Nilsson, Kongl. Vet. akad. Handl. Stockholm.

1880 Halichoerus grypus Allen, History of North American pinnipeds. p. 689.

Gray (silvery, ashy or dusky) with ill-defined dark spots. Total length 2450 (7 ft) to 3150 (9 ft). (grýpus; Lat., hook-nosed)

The gray seal occurs on the northern coasts of western Europe and eastern North America. Its southward range in America extends about to Nova Scotia.

Genus Phoca Linnaeus

1758 Phoca Linnaeus, Systema naturae. ed. 10. 1:37. Type Phoca vitulina Linnaeus.

Teeth 34 *(four front teeth in lower jaw)*; the cheek teeth large and strong, *not falling out with age;* braincase forming nearly one half of length of skull; forehead high, arched. (Phóca; Lat., a seal)

The genus Phoca is widely distributed on the coasts of the northern hemisphere. About a half dozen species are known, three of which occur within our limits.

SPECIES OF PHOCA

Male whitish with a black stripe crossing shoulder and running back along sides (subgenus Pagophilus Gray) .... P. groenlandica

Male not white with black markings

First finger slightly longer than others; back generally blackish with whitish spots (subgenus Pusa Scopoli) .... P. hispida

First finger not longer than others; back generally light brown or gray with dark spots (subgenus Phoca) .... P. vitulina

Phoca groenlandica Fabricius *Harp seal*

1776 Phoca groenlandica Fabricius, Müller's Zool. Dan. prodr., 8. (Coast of Greenland)

1880 Phoca groenlandica Allen, History of North American pinnipeds, p. 630.

Male whitish, with black face, and a black stripe crossing shoulders and extending backward along sides. Female less distinctly marked. Total length (male) about 1750 (5 ft), female smaller. (groenlándica; N. Lat., pertaining to Greenland)

The harp seal is a circumpolar species, confined to the icy northern seas. In America its southward range extends to Newfoundland and the Magdalen islands.

Phoca hispida Schreber *Ringed seal*

1775 Phoca hispida Schreber, Säugethiere. 3:312.
1880 Phoca foetida Allen, History of North American pinnipeds, p. 597.

First finger longest, the others successively decreasing in length. General color blackish brown above, yellowish white below, the back with large oval whitish spots; muzzle and eye ring usually black. Total length (male) about 1750 (5 ft), female smaller. (híspida; Lat., harsh)

The ringed seal occurs on the Arctic coasts of both hemispheres. In eastern North America its range extends to Labrador and Newfoundland.

Phoca vitulina Linnaeus *Harbor seal*

1758 [Phoca] vitulina Linnaeus, Systema naturae. ed. 10. 1:38. (Coast of Europe)
1880 Phoca vitulina Allen, History of North American pinnipeds, p. 559.

Fingers not distinctly graduated; general color grayish or brownish; paler below; the back with dark spots, muzzle and eye ring usually yellowish. Total length about 1750 (5 ft); female smaller. (vitulína; Lat., calf-like)

The harbor seal is peculiar to the north Atlantic. Its normal range in North America extends about to Long Island, though individuals straggle much farther south. It is frequently taken in rivers and lakes at some distance from the sea.

Family **Felidae** *Cats*

Heel never applied to ground in walking; claws sharp, compressed, retractile, *hind toes* 4; *teeth* 28 *or* 30; head short, round. (Félida , genus Felis)

The well known cat family, though distributed throughout the warmer parts of the world (Australia and neighboring islands excepted) contains only a small number of genera. Two are all that are commonly recognized, but this number should probably be doubled. Two only occur in America, both of which are found in the northeastern United States.

GENERA OF FELIDAE

Tail long; teeth 30 .... Felis
Tail short; teeth 28 .... Lynx

Genus **Felis** Linnaeus

1758 Felis Linnaeus, Systema naturae. ed. 10. 1:41. Type Felis catus Linnaeus.

Form slender; tail long; teeth 30; no mane; ears not tufted; pupil of eye when contracted a vertical slit. (Félis; Lat., a cat)

The range of the genus Felis is the same as that of the family. Some 50 species are known, about a dozen of which occur in America

north of Panama. The following is the only wild[1] species found in northeastern North America.

Felis oregonensis Rafinesque *Puma*

Yellowish brown above, middle line of back darker; under parts whitish; feet large and heavy. (oregonénsis; N. Lat., Oregonian)

While its typical subspecies F. oregonensis oregonensis is confined to the northwest coast region, the puma occurs throughout the wilder parts of North America south of the upper part of the Canadian zone. It is divisible into several geographic races, one of which is found within our limits.

Felis oregonensis hippolestes (Merriam) *Northern puma*

1897 Felis hippolestes Merriam, Proc. biolog. soc. Washington. 15 July 1897. 11:219. (Wind river mountains, Wy.)

1898 Felis oregonensis hippolestes Stone, Science. n. s., 6 Jan. 1899. 9:35.

Total length, 2600 (8½ ft); tail vertebrae, 930 (36½); hind foot, 270 (10⅝). (hippoléstes; Gk., horse thief)

The northern puma formerly occurred throughout the wooded portions of the northeastern United States and southern Canada. It is now exterminated except in the remotest districts. This is the Felis concolor of writers on the mammals of eastern North America. True Felis concolor is, however, confined to South America. The proper subspecific name for the puma of the northeastern United States is still a matter of doubt. I use hippolestes provisionally only.

Genus Lynx Kerr

1792 Lynx Kerr, Animal kingdom, 1, Systematic catalogue (inserted between p. 32 and 33). Type Lynx vulgaris Kerr=Felis lynx Linnaeus.

Form robust; tail short; *teeth 28;* ears tufted; otherwise as in Felis.

The genus Lynx contains a dozen or more species, confined for the most part to the middle and lower boreal regions o the northern hemisphere. About a dozen species or races, the status of which is not yet well understood, occur in North America. Four of these are found within our limits.

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[1] The house cat is often found in a half wild state.

SPECIES OF LYNX

Feet very large; tail very short; fur long and loose; ear tufts long; skull broad (subgenus Lynx)
  Upper parts light (a mixture of dark brown and gray).... L. canadensis
  Upper parts dark (a mixture of black and hazel).......... L. subsolanus
Feet moderate; tail moderate; fur short and dense; ear tufts short; skull narrow (subgenus Cervaria)
  Color rich, with much black on upper parts; greatest length of skull about 132 (5¼).. L. gigas
  Color dull, little black on upper parts; greatest length of skull about 120 (4¾).. L. ruffus

Lynx canadensis Kerr *Canada lynx*

1792 Lynx canadensis Kerr, Animal kingdom, 1, Systematic catalogue (inserted between p. 32 and 33), no. 298. (Canada)

Back a grizzle of dark brown and light gray; belly dirty white; ear tufts about 50 (2). Total length, 1000 (39½); tail vertebrae, 100 (4); hind foot, 225 (8⅞); breadth of front foot about 80 (3$\frac{3}{16}$). (canadénsis; N. Lat., Canadian)

The Canada lynx occurs in the forested region of "the whole of boreal North America from Maine and northern New York to Alaska, but now very rare and apparently becoming extirpated in the east."—*Bangs*

Lynx subsolanus Bangs *Newfoundland lynx*

1897 Lynx subsolanus Bangs, Proc. biolog. soc. Washington. 16 Mar. 1897. 11: 49. (Codroy, Newfoundland)

Back a grizzle of black and hazel; belly pale yellowish brown with irregular spots of black. Total length, 920 (36); tail vertebrae, 110 (4¼); hind foot, 220 (8⅝); breadth of front foot about 75 (3) (subsolánus; Lat., under the east wind, i. e. eastern)

The Newfoundland lynx is confined to the island of Newfoundland.

Lynx ruffus (Gueldenstaedt) *Bay lynx; wildcat*

1776 Felis ruffus Gueldenstaedt, Novi. comment. acad. scient. Imp. Petropolitanae (1775), 20: 484. 1776.

1897 Lynx ruffus Rhoads, Proc. acad. nat. sci. Philadelphia. p. 32.

Back yellowish gray tinged with rufous, much spotted and streaked with black; belly whitish spotted with black; a brownish collar on throat. Total length 900 (35½); tail vertebrae, 170 (6¾); hind foot, 180 (7⅛); breadth of front foot about 50 (2). (rúffus; Lat., reddish)

The wildcat ranges from northern Georgia to the coast of Maine. It is often common in comparatively thickly settled districts. The species is divisible into numerous subspecies, of which the typical form only (L. ruffus ruffus) occurs within our limits.

Lynx gigas Bangs *Nova Scotia lynx*

1897 Lynx gigas Bangs, Proc. biolog. soc. Washington. 16 Mar. 1897. 11: 50. (15 miles back of Bear river, Nova Scotia)

Back cinnamon rufus, much spotted and streaked with black; belly dull white, spotted with black; a collar of cinnamon on throat. Total length, 1000 (39); tail vertebrae, 180 (7); hind foot, 200 (8); breadth of front foot about 50 (2). (gígas; Lat., a giant)

The Nova Scotia lynx is confined to the forested regions of the peninsula of Nova Scotia.

Family Canidae *Dogs*

Heel never applied to the ground in walking, claws blunt, not compressed or retractile; hind toes 4; teeth 42 or more; head generally long and narrow. (Cánidae; genus Canis)

The dog family is even more widely distributed than are the cats, since some of its members reach the highest northern limits of mammalian life. Like the cat family it contains a few genera only. Three of these occur in North America, and all are found within our limits.

GENERA OF CANIDAE

Upper front teeth distinctly lobed; pupil of eye circular................ Canis
Upper front teeth without lobes; pupil of eye elliptic
  Tail without concealed mane and with abundant soft under-fur..... Vulpes
  Tail with a concealed mane of stiff hairs and without soft fur......Urocyon

Genus Canis Linnaeus

1758 Canis Linnaeus, Systema naturae. ed. 10, 1:38. Type Canis familiaris Linnaeus.

Teeth 42, upper front teeth distinctly lobed; pupil of eye circular. (Cánis Lat., a dog)

This extensive genus may be considered as truly cosmopolitan. One or more species occur in every part of the American continent from Greenland to Patagonia and the Falkland isles; and similarly in the old world, Europe, Africa and Asia, with most of the large islands adjacent, and even Australia, have their wild dogs, though in the last case they may belong to a feral race, introduced originally by man.—*Flower & Lydekker*. A dozen or more species occur in North America, only two of which are found within our limits.

SPECIES OF CANIS

Fur white in winter .... C. albus
Fur always dark .... C. occidentalis

Canis albus (J. Sabine) *Arctic wolf*

1823 Canis lupus albus J. Sabine, Franklin's journal, appendix, p. 655. (Fort Enterprise)

1898 Canis albus Bangs, American naturalist. July 1898. 32:505.

Fur white in winter. (This animal is very slightly known. I have seen no specimens, nor can I find reliable published measurements.) (álbus; Lat., white)

The arctic wolf inhabits the barren arctic regions of America. Within our limits it is confined to northern Labrador.

Canis occidentalis (Richardson) *American wolf*

1829 Canis lupus, occidentalis Richardson, Fauna Boreali-Americana. 1:60. (Northern North America)

1898 Canis occidentalis Bangs, American naturalist. July 1898. 32:505.

Back brownish or blackish mixed with tawny; belly light tawny or dirty whitish. Total length, 1465 (57); tail vertebrae, 405 (16); hind foot, 225 (9). (occidentális; Lat., western, i. e. inhabiting the western hemisphere)

The American wolf is now exterminated within our limits in all but the wildest and most sparsely settled regions. The exact boundaries of the animal's range are unknown.

Genus Vulpes Richardson

1829 Vulpes Richardson, Fauna Boreali-Americana. 1:83–91. Based on the American foxes.

Teeth 42; upper front teeth not lobed; pupil of eye elliptic; *tail with a uniform coat of long hair and an abundant soft under-fur.* (Vúlpes; Lat., a fox)

The genus Vulpes contains a half dozen or more species, all of which are peculiar to the northern hemisphere. Four or more occur in North America. Three of these are found within our limits.

SPECIES OF VULPES

Ear rounded, scarcely overtopping fur, color bluish gray in summer, white in winter .... V. lagopus
Ear pointed, long and conspicuous; fur normally fulvous or reddish at all seasons (occasionally black or gray)
Claws short, mostly hidden by the fur; color dark .... V. fulvus
Claws very long and conspicuous; color pale .... V. deletrix

Vulpes lagopus (Linnaeus) *Arctic fox*

1758 [Canis] lagopus Linnaeus, Systema naturae. ed. 10. 1: 40 (Lapland)
1854 Vulpes lagopus Audubon and Bachman, Quadr. N. Am. 3: 89.

Fur dark bluish gray in summer, turning to pure white in winter; sooty black individuals occasionally found. Total length, 1100 (43½); tail vertebrae, 350 (13¾); hind foot, 145 (5¾); ear, 45 (1¾). (lagópus; Gk., hare foot)

The arctic fox occurs in the arctic regions of both hemispheres. It ranges throughout northern Labrador and on the coast occasionally reaches James bay and the strait of Belle Isle.

Vulpes fulvus (Desmarest) *Red fox*

Reddish; feet and ears blackish; tip of tail white; ear pointed, about 80 (3⅛) in length. The following color variations occur more commonly in the northern part of the animal's range than elsewhere. *The cross fox*, like the last but with a dark half ring on back of neck crossed by a dark line along middle of back. *The silver fox* entirely silver gray. *The black fox* entirely blackish. All of these phases intergrade with each other and with the red phase. (fúlvus; Lat., yellowish)

The well known red fox ranges throughout the greater part of North America south to the lower edge of the upper austral zone. Two subspecies are known within our limits.

SUBSPECIES OF VULPES FULVUS

Upper parts tawny yellowish; total length, 1000 (39½) .... V. fulvus fulvus
Upper parts bright rust color; total length, 1080 (42½) .... V. fulvus rubricatus

Vulpes fulvus fulvus (Desmarest) *Southeastern red fox*

1820 Canis fulvus Desmarest, Mammalogie. 1:203. (Virginia)
1842 Vulpes fulvus DeKay, Zoology of New York, Mammalia, p. 44.

Back tawny yellowish, never strongly rust color. Total length, 1000 (39½); tail vertebrae, 360 (14); hind foot, 150 (5⅞). (fúlvus; Lat., yellowish)

The southeastern red fox is common throughout the eastern United States south to the lower edge of the upper austral zone. The northern limits of range is not yet known.

Vulpes fulvus rubricatus Bangs *Nova Scotia red fox*

1897 Vulpes pennsylvanica vafra Bangs, Proc. biolog. soc. Washington, p. 53. (not Canis vafer Leidy)
1898 Vulpes pennsylvanica rubricata Bangs, Science. n. s. 25 Feb. 1898. 7: 272. (Digby N. S.)

Back bright rust color. Total length, 1080 (42½); tail vertebrae, 400 (15¾); hind foot, 160 (6¼). (rubricátus; Lat., reddened)

The Nova Scotia red fox is not at present known to occur outside of

the peninsula of Nova Scotia. The relationships of this race, the typical form and the large form occurring in the Hudsonian zone of Ontario and Quebec are not well understood.

Vulpes deletrix Bangs *Newfoundland red fox*

1898 Vulpes deletrix Bangs, Proc. biolog. soc. Washington. 24 Mar. 1898. 12 : 36. (Bay St George, Newfoundland)

Like Vulpes fulvus, but hind foot *proportionally very large*; claws long and stout; color in red phase pale ocher yellow; black and silver gray phases very common. Total length, 960 (37¾); tail vertebrae, 336 (13); hind foot, 160 (6¼). (delétrix Lat., a destroyer)

The Newfoundland fox is confined to the island of Newfoundland.

Genus Urocyon Baird

1857 Urocyon, Baird, Mamm. N. Am. p. 121. Type Canis virginianus Erxleben=C. cinereoargenteus Müller.

Teeth 42, upper front teeth not lobed; pupil of eye elliptic; *tail with a concealed mane of stiff hairs and no soft under-fur.* (Urocýon; Gk., tail dog)

Peculiar to the new world. Ranges from South America north to the lower edge of the transition zone in the eastern United States. Several species are known, two of which occur in North America. Only one of these is found within our limits.

Urocyon cinereoargenteus (Müller) *Gray fox*

1776 Canis cinereoargenteus Müller, Natursyst. Suppl. p. 29. (Eastern United States)

1894 Urocyon cinereoargenteus Rhoads. American naturalist. June 1894. 28 : 524.

Back a coarse grizzle of blackish and white, belly tawny; region about ears tawny; a black line along back of tail. Total length, 900 (35½); tail vertebrae, 260 (10¼); hind foot, 125 (5). (cinereoargénteus; Lat., gray-silvered)

The gray fox ranges throughout the southern United States from Atlantic to Pacific. It is divisible into six or more geographic races. The typical subspecies alone, Urocyon cinereoargenteus cinereoargenteus, occurs within our limits. It is common in the region east of the Alleghanies from Long Island and the lower Hudson valley southward.

Family Mustelidae *Weasels*

Entire sole to heel not habitually applied to ground in walking; claws never fully retractile; hind toes five; teeth 32 to 38; head variable in form. (Mustélidae; genus Mustela)

The family Mustelidae is distributed throughout both hemispheres with the exception of the Australian region. It contains about twenty genera, nine of which occur in North America. Five of these are found within our limits.

GENERA OF MUSTELIDAE

Toes conspicuously webbed; the whole animal highly modified
for an aquatic life (otters)........................ Lutra, p. 130
Toes not conspicuously webbed; animal not specially modified
for an aquatic life
Teeth 38
Body stout; part of sole applied to ground in walking
(wolverine).. Gulo, p. 131
Body slender; only the toes applied to ground in
walking (martins and fishers)..................... Mustela, p. 132
Teeth 34
Tail closely furred; claws short (weasels)............. Putorius, p. 133
Tail bushy; claws long (skunk)....................... Mephitis, p. 136

Genus Lutra Brisson

1756 Lutra Brisson, Regnum animale in classes 9 distributum. Type Mustela lutra Linnaeus.

Teeth 36; feet short and rounded; toes webbed; claws small, curved, blunt; head broad, flat; tail thick at base, tapering; fur short and dense. (Lútra; Lat., an otter)

The genus Lutra is distributed throughout the greater part of the world, north to the limit of tree growth. It is not found in the Australian region. A dozen or more species are known, two of which occur in eastern North America.

SPECIES OF LUTRA

Total length about 1100 ($43\frac{3}{8}$); skull about 105 ($4\frac{1}{8}$)......... L. hudsonica
Total length about 995 ($39\frac{1}{4}$); skull about 95 ($3\frac{3}{4}$).............. L. degener

Lutra hudsonica (Desmarest) *North American otter*

Size large; total length about 1100 ($43\frac{3}{8}$); greatest length of skull about 105 ($4\frac{1}{8}$). (hudsónica; N. Lat., Hudsonian)

The North American otter inhabits marshes, lakes and watercourses throughout the continent of North America from the extreme north at least to the southern boundary of the United States. It is divisible into four or more subspecies, two of which occur within our limits.

SUBSPECIES OF LUTRA HUDSONICA

General color dark; webs between toes densely
haired below.............................. L. hudsonica hudsonica
General color light; webs between toes sparsely
haired below.............................. L. hudsonica lataxina

Lutra hudsonica hudsonica (Desmarest) *Northeastern otter*

1803 Mustela hudsonica Desmarest, Nouv. dict. d'hist. nat. 13:384. (Eastern Canada)

1831 Lutra hudsonica F. Cuvier, Suppl. Oeuvres de Buffon. 1:194.

1898 Lutra hudsonica Rhoads, Trans. Am. philos. soc. n. s. Oct. 1898. 20:424.

Upper parts seal brown; under parts grayish brown; *under surface of webs between toes densely hairy.* Total length, 1100 (43⅜); tail vertebrae, 420 (16½); hind foot, 120 (4⅜). (h u d s ó n i c a; N. Lat., Hudsonian)

The northeastern otter occurs throughout the less densely inhabited portions of eastern North America from the lower edge of the transition zone northward.

Lutra hudsonica lataxina (F. Cuvier) *Southeastern otter*

1823 L u t r a l a t a x i n a F. Cuvier, Dict. des sci. nat. 27:242. (South Carolina)

1898 L u t r a h u d s o n i c a l a t a x i n a Rhoads, Trans. Am. philos. soc. n. s. Oct. 1898. 20:427.

Upper parts yellowish brown; under parts light grayish brown; *under surface of webs between toes sparsely hairy.* Total length, 1100 (43⅜); tail vertebrae, 420 (16½); hind foot, 125 (4⅞). (l a t a x í n a; N. Lat., like the genus L a t a x)

The southeastern otter occupies the austral zones of the eastern United States north of the peninsula of Florida, where it gives way to the Florida otter, L. h u d s o n i c a v a g a Bangs.

Lutra degener Bangs *Newfoundland Otter*

1898 L u t r a d e g e n e r Bangs, Proc. biolog. soc. Washington. 24 Mar. 1898. 12:35. (Bay St George, Newfoundland)

1898 L u t r a d e g e n e r Rhoads, Trans. Am. philos. soc. n. s. Oct. 1898. 20:433.

Size small, total length about 995 (39¼); greatest length of skull about 95 (3⅜); hind foot about 112 (4⅜); color blackish. (d é g e n e r; Lat., degenerate)

The Newfoundland otter is confined to the island of Newfoundland.

Genus **Gulo** Storr

1780 G u l o Storr, Prodr. meth. mamm. p. 34. Type U r s u s g u l o Linnaeus.

Part of sole applied to ground in walking, body stout; claws *large,* compressed, curved; ears very short; tail *short, bushy;* teeth 38. (G ú l o; Lat., a glutton)

The genus G u l o contains two species only, both inhabitants of the northern hemisphere, G. g u l o of the old world, and the following:

Gulo luscus (Linnaeus) *Wolverine*

1758 U r s u s l u s c u s, Linnaeus, Systema naturae. ed. 10. 1:47. (Hudson bay)

1823 G u l o l u s c u s J. Sabine, Franklin's journal, p. 650.

Dark brown or blackish; a pale area on sides. Total length, 760 (30); tail vertebrae, 200 (8); hind foot, 170 (6⅜). (l ú s c u s; Lat., one-eyed)

The wolverine inhabits the boreal forests of North America. Within our limits it is now chiefly, if not wholly confined to Canada.

Genus **Mustela** Linnaeus

1758 Mustela Linnaeus, Systema naturae. ed. 10. 1:45. Type by elimination Mustela martes Linnaeus.

Only the toes applied to ground in walking; body slender; claws *small,* sharp partly retractile; ears short; tail long, not conspicuously bushy; *teeth* 38. (Mustéla; Lat., a martin)

The genus Mustela occurs throughout the forested boreal regions of the northern hemisphere. About a dozen species are known. Four of the five American forms occur within our limits.

SPECIES OF MUSTELA

Length over 760 (30); ear low, rounded (Fisher) .... M. pennanti
Length under 760 (30); ear high, pointed (Martin)
Greatest length of skull about 85 (3⅜) .... M. brumalis
Greatest length of skull about 80 (3⅛)
General color light rich brown .... M. americana
General color deep chocolate brown .... M. atrata

Mustela pennanti Erxleben *Fisher*

1777 Mustela pennanti Erxleben, Syst. regn. anim. 1:470. (Eastern Canada)

Dark brown or blackish, darker on under parts; *no pale throat patch; ears low and rounded.* Total length, 890 (35); tail vertebrae, 355 (14); hind foot, 120 (4¾). (pennánti; name from that of Thomas Pennant)

The fisher occurs in the boreal forests of North America from Maine and southern Labrador west to the Pacific coast. The typical subspecies M. pennanti pennanti is the only geographic race found within our limits.

Mustela brumalis Bangs *North Labrador martin*

1898 Mustela brumalis Bangs. American naturalist. July 1898. 32:502. (Okak Labrador)

Dimensions of skull (the only part of the animal now known); greatest length, 85 (3⅜); width of muzzle across canines, 17.2 (11/16). (brumális; Lat., wintery northern)

The north Labrador martin is known from three skulls collected at Okak Labrador.

Mustela americana Turton *Eastern martin*

1800 Mustela americana Turton, System of nature. 1:60. (Eastern North America)

General color *light rich brown, slightly paler on under parts;* throat usually with a light (tawny or whitish) patch; *ears high pointed.* Total length, 610 (24);

tail vertebrae, 205 (8); hind foot 90 ($3\frac{1}{2}$). Skull: greatest length, 80 ($3\frac{1}{8}$); width of muzzle across canines, 14 ($\frac{9}{16}$). (Americána; N. Lat., American)

The eastern pine martin inhabits the boreal forests of North America from the Atlantic coast west at least to the Rocky mountains. On the Pacific coast it is replaced by the closely related M. caurina Merriam. It is still common in northern New England and northern New York.

Mustela atrata Bangs *Newfoundland martin*

1897 Mustela atrata Bangs, American naturalist. Feb. 1897. 31:162. (Bay St George, Newfoundland).

General color *deep chocolate* and black; throat patch orange. Total length, 550 ($17\frac{3}{4}$); tail vertebrae, 185 ($7\frac{1}{4}$); hind foot, 88 ($3\frac{1}{2}$). (atráta; Lat., wearing mourning)

The Newfoundland martin is confined to the island of Newfoundland.

Genus Putorius Cuvier

1817 Putorius Cuvier, Régne animal. 1:147. Type Mustela putorius Linnaeus.

Like Mustela, but *teeth only* 34. (Putórius; Lat., a bad odor)

The genus Putorius is widely distributed in Europe, Asia, Africa, North America and South America. 50 or more forms will doubtless eventually be recognized. In America north of Panama, 22 are now known to occur, and four of these are found within our limits.

SPECIES OF PUTORIUS

Total length over 500 (20); (subgenus Lutreola Wagner) .... P. vison

Total length under 500 (20); toes without webs (subgenus Arctogale Kaup)

- Tail forming about one fourth of total length .... P. cicognanii
- Tail forming about one third of total length
  - Tail slender and closely haired, its black tip short (about 60 ($2\frac{3}{8}$) in male, 28 ($1\frac{1}{8}$) in female) .... P. occisor
  - Tail somewhat bushy, its black tip long (about 80 ($3\frac{1}{8}$) in male, 50 (2) in female) .... P. noveboracensis

Putorius vison (Schreber) *Mink*

Total length over 500 (20); color brown throughout varying much in exact shade; chin usually spotted with white. (víson; derivation not known)

The mink ranges throughout the greater part of North America north of Mexico. It is divisible into half a dozen or more geographic races, two of which occur within our limits.

SUBSPECIES OF PUTORIUS VISON

Total length under 600 ($23\frac{1}{2}$); color blackish brown .... P. vison vison
Total length over 600 ($23\frac{1}{2}$); color chestnut brown .... P. vison lutreocephalus

Putorius vison vison (Schreber) *Northeastern mink*

1778 Mustela vison Schreber, Säugethiere, 3: 463 (eastern Canada)
1896 Putorius vison Bangs, Proc. Boston soc. nat. hist. 1896. 27: 3.

Color rich dark brown, *often nearly black.* Total length, 520 ($20\frac{1}{2}$); tail vertebrae, 185 ($7\frac{1}{4}$); hind foot, 55 ($2\frac{3}{16}$).

The northeastern mink inhabits the border of watercourses in the boreal forests of northern North America, south into the northern tier of states. West of the Rocky mountains it is replaced by the larger P. vison energumenos Bangs.

Putorius vison lutreocephalus (Harlan) *Southeastern mink*

1825 Mustela lutreocephala Harlan, Fauna americana, p. 63.
1896 Putorius vison lutreocephalus Bangs, Proc. Boston soc. nat. hist. Ap. 1896. 27: 4.

Color dark chestnut brown, the tail darker. Total length, 635 (27); tail vertebrae, 210 ($8\frac{1}{4}$); hind foot, 70 ($2\frac{3}{4}$). (lutreocéphalus; Lat. and Gk., otter head)

The southeastern mink inhabits the borders of watercourses in the transition zone and upper austral zone of the eastern United States, from central New York and the coast of Maine southward. In the lower austral zone it is replaced by two nearly related forms, P. vison vulgivagus Bangs, of the gulf coast, and P. vison lutensis Bangs, of the south Atlantic coast.

Putorius cicognanii (Bonaparte) *Small brown weasel*

1838 Mustela cicognanii Bonaparte, Charlesworths magazine. Jan. 1838. 2:37. (Eastern United States)
1839 Putorius cicognanii Richardson, Zoölogy of Beechey's voyage of the blossom, p. 10 *.
1896 Putorius cicognani Merriam, North American fauna. 30 June 1896. no. 11, p. 10.

Color in summer dark brown above, pure white below, ***tail forming about one fourth of total length,*** the terminal third black, winter coat pure white except tip of tail, which remains black. Total length, male, 285 ($11\frac{1}{4}$),

female, 225 (10); tail vertebrae, male, 77 (3⅛), female, 69 (2⅝); hind foot, male, 37 (1½), female, 30 (1$\frac{3}{16}$.) (cicognánii; name from that of Felice Cicognani)

The small brown weasel inhabits woods and fields in the boreal and transition zones throughout eastern North America from the limit of tree growth south to Long Island and in the mountains probably much farther. The change to the white winter coat always takes place. The form occurring within our limits is the typical subspecies P. cicognanii cicognanii. In northwestern British America and in Alaska this is replaced respectively by P. cicognanii richardsoni (Bonaparte) and P. cicognanii alascensis (Merriam).

Putorius occisor Bangs *Slender-tailed weasel*

1899 Putorius occisor Bangs, Proc. New England zoölogical club. 9 June 1899. 1:54. (Bucksport Me.)

Tail closely haired, forming nearly one third of total length, *its black tip short* (about 60 (2⅝) in male, 30 (1⅛) in female) and *mostly confined to the terminal tuft of hair;* winter coat pure white except the black tip of tail and a slight wash of pale yellow on belly; summer coat not known. Total length, male, 460 (18), female, 350 (13⅝); tail vertebrae, male, 170 (6⅝), female, 115 (4½); hind foot, male, 50 (2), female, 36 (1$\frac{7}{16}$). (occísor; Lat., a slayer)

The slender-tailed weasel is at present very slightly known. It probably occurs in the forests of the Canadian zone from Maine to Manitoba. Like the New York weasel, it is remarkable for the great difference in size between the sexes.

Putorius noveboracensis Emmons *New York weasel*

Tail somewhat bushy, forming about one third of total length, *its black tip long* (about 80 (3⅛) in male, 50 (2) in female) *and extending considerably beyond the terminal tuft of hairs* (often occupying nearly one half of tail); summer coat brown above, white or yellow below; winter coat white (northern) or drab (southern). Total length, male, 405 (16), female, 325 (12⅝); tail vertebrae, male, 140 (5½), female, 108 (4¼); hind foot, male, 47 (1⅞), female, 34 (1¼). (noveboracénsis; N. Lat., pertaining to New York)

The New York weasel inhabits woods and fields in the transition and upper austral zones throughout the eastern United States from Maine and New York to North Carolina. The change to the white winter coat always takes place in the northern part of the animal's range; at the south the change is to a drab coat. The latter is not well understood. This species is divisible into two geographic races.

SUBSPECIES OF PUTORIUS NOVEBORACENSIS

Under parts white .... P. noveboracensis noveboracensis
Under parts yellow .... P. noveboracensis notius

Putorius noveboracensis noveboracensis Emmons *White-bellied New York weasel*

1840 Putorius noveboracensis Emmons, Report on the quadrupeds of Massachusetts, p. 45. (Southern New York)

1896 Putorius noveboracensis Merriam, North American fauna. 30 June 1896. no. 11, p. 16. (part)

Under parts always pure white; winter coat white. (noveboracénsis; N. Lat., pertaining to New York)

The white-bellied New York weasel occupies the range of the species north of the upper austral zone.

Putorius noveboracensis notius Bangs *Yellow-bellied New York weasel*

1896 Putorius noveboracensis Merriam, North American fauna. 30 June 1896. no. 11, p. 16. (part)

1899 Putorius noveboracensis notius Bangs, Proc. New England zoological club. 9 June 1899. 1: 53. (Weaverville, Buncombe co. N. C.)

Under parts always pale yellow; winter coat drab. (nótius; Lat., southern)

The yellow-bellied New York weasel is confined to the austral zones of the eastern United States. The exact limits of its range are not known.

Genus Mephitis Cuvier

1800 Mephitis Cuvier, Leçons d'anat. comp., 1, Tab. gen. des classes des anim. (facing p. 522). Based on "les Moufettes". Described in Tab. elem. d' hist. nat. des anim. 1798. p. 116.

Part of sole applied to ground in walking; body stout; claws large, curved and strong; ears short; *tail very long and bushy; teeth* 34; *secretion of anal glands* (not urine as commonly supposed) *so copious and offensive as to be the animal's chief weapon of defense.* (Mephítis; Lat., a bad odor)

The genus Mephitis is peculiar to America, where it is very generally distributed. It probably contains a dozen or more species, half of which occur in North America. Only one is found within our limits.

Mephitis mephitica (Shaw) *Common skunk*

Black, with a white stripe on forehead; a white patch on nape; a white stripe extending backward from nape patch for a varying distance on each side of body; and a white tip to tail; *tail slightly more than one third of total length, the terminal brush tapering.* (mephítica; Lat., having a bad odor)

The common skunk inhabits both forests and cleared lands throughout the greater part of eastern North America. It is divisible into two subspecies.

SUBSPECIES OF MEPHITIS MEPHITICA

Hind foot 83 ($3\frac{5}{16}$).. M. mephitica mephitica
Hind foot 65 ($2\frac{5}{8}$).. M. mephitica scrutator

Mephitis mephitica mephitica (Shaw) *Northeastern skunk*

1792 Viverra mephitica Shaw, Museum Leverianum, p. 172. (North America; name afterward restricted to the northern form)

1895 Mephitis mephitica Bangs, Proc. Boston soc. nat. hist. 31 July 1895. 26: 533.

1896 Mephitis mephitica mephitica Bangs, Proc. biolog. soc. Washington. 28 Dec. 1896. 10: 140.

Total length, 650 ($25\frac{5}{8}$); tail vertebrae, 165 ($6\frac{1}{2}$); hind foot 83 ($3\frac{5}{16}$). (mephítica; Lat., having a bad odor)

The northeastern skunk inhabits the boreal zone of eastern North America.

Mephitis mephitica scrutator Bangs *Southeastern skunk*

1896 Mephitis mephitica scrutator Bangs, Proc. biolog. soc. Washington. Dec. 1896. 10: 141. (Carterville, Acadia parish, La.)

Total length 590 ($23\frac{1}{4}$); tail vertebrae, 210 ($8\frac{1}{4}$); hind foot, 65 ($2\frac{5}{8}$). (scrutátor; Lat., an examiner)

The southeastern skunk inhabits the austral zones of the eastern United States. In the transition zone it gradually merges into M. mephitica mephitica.

Family Procyonidae *Racoons*

Whole sole to heel applied to ground in walking; claws not retractile; hind toes 5; *teeth* 36 *to* 40; *size medium; tail well developed.* (Procyónidae; genus Procyon)

The Procyonidae are typically tropical American, though one genus is oriental. Seven or eight genera are now usually placed in this family, though the number is probably too great. Two of these occur in the United States, and one is found within our limits.

Genus Procyon Storr

1780 Procyon Storr, Prodr. meth. mamm. p. 35. Type Ursus lotor Linnaeus.

Form stout; tail short, cylindric; head round; muzzle pointed; *teeth* 40. (Procýon; Gk., false dog)

The genus Procyon ranges from tropical South America north through Mexico about to the northern limit of the United States. It contains several species, only one of which occurs in North America.

Procyon lotor (Linnaeus) *Racoon*

1758 [Ursus] lotor Linnaeus, Systema naturae. ed. 10. 1:48. (Eastern United States)

1780 Procyon lotor Storr, "Prodr. meth. mamm."

Yellowish brown, the hairs tipped with black; tail ringed with black; a black area about eye. Total length, 830 (32⅝); tail vertebrae, 250 (9⅞); hind foot, 120 (4¾). (lótor; Lat., one who washes)

The racoon occurs throughout the forested regions of North America south of the lower edge of the boreal zone. The form found within our limits is typical Procyon lotor lotor. In Florida this is replaced by P. lotor elucus Bangs.

Family **Ursidae** *Bears*

Whole sole to heel applied to ground in walking; claws not retractile; hind toes 5; teeth 40 to 42; *size very large;* tail rudimentary. (Úrsidae; genus Ursus)

The family Ursidae is widely distributed throughout both hemispheres outside of Africa and Australia. Four genera are usually recognized, but this number will doubtless be increased. Two occur in North America and both of these are found within our limits.

GENERA OF URSIDAE

Head long and narrow; cheek teeth relatively small and weak; color always white .... Thalarctos

Head short and broad; cheek teeth relatively large and strong; color never white .... Ursus

Genus **Thalarctos** Gray

1825 Thalarctos Gray, Annals of philosophy. n. s. July 1825. 10:62. Type Ursus maritimus Linnaeus. (Thalarctos polaris Gray)

Head long and narrow; cheek teeth small and weak relatively to size of skull; *color always white.* (Thalárctos; Gk., sea bear)

The genus Thalarctos occurs in the polar regions of both eastern and western hemispheres. Only one species is at present recognized.

Thalarctos maritimus (Phipps) *Polar bear*

1774 Ursus maritimus Phipps. A voyage toward the north pole, p. 185. (Spitzbergen)

1899 Thalarctos maritimus Stejneger, Science. 15 Sep. 1899. 10:378.

White at all seasons. Total length, 2135 (7 ft). (marítimus Lat., maritime)

The range of the polar bear in eastern North America extends as far south on the Atlantic coast of Labrador as the strait of Belle Isle. The animal is nowhere found far away from salt water.

Genus **Ursus** Linnaeus

1758 U r s u s Linnaeus, Systema naturae. ed. 10. 1 : 47. Type U r s u s a r c t o s Linnaeus.

Head short and broad; cheek teeth large and strong relatively to size of skull; *color never white.* (Úr s u s; Lat., a bear)

The distribution of the genus U r s u s is essentially the same as that of the family to which it belongs. The species are at present little known; probably 30 or more forms will eventually be recognized. About a dozen occur in North America, only one of which is certainly known within our limits. It is a member of the subgenus E u a r c t o s.

Ursus americanus Pallas *Black bear*

Front claws slightly if at all longer than the hind ones; color black or dark brown, the exact shade variable; length of skull under 350 (13$\frac{3}{4}$). (a m e r i c á n u s; N. Lat., American)

The black bear is widely distributed in North America from Mexico and the gulf states northward It is divisible into numerous geographic races, at least two of which occur within our limits.

SUBSPECIES OF URSUS AMERICANUS

Length of adult skull about 250 (9$\frac{7}{8}$)........ U. a m e r i c a n u s a m e r i c a n u s
Length of adult skull about 200 (8)........... U. a m e r i c a n u s s o r n b o r g e r i

Ursus americanus americanus Pallas *Northern black bear*

1780 U r s u s a m e r i c a n u s Pallas, Spicilegia zoologica. fasc. 14, p. 5. (North America)

1896 U r s u s a m e r i c a n u s Merriam, Proc. biolog. soc. Washington. 13 Ap. 1896. 10 : 79.

Skull long and narrow, its greatest length about 250 (9$\frac{7}{8}$). (a m e r i c á n u s; N. Lat., American)

The northern black bear is abundant throughout the wilder forested parts of the boreal and transition zones of eastern North America. The characters of the bear inhabiting the austral zones are not at present understood.

Ursus americanus sornborgeri Bangs *Labrador black bear*

1898 U r s u s (E u a r c t o s) a m e r i c a n u s s o r n b o r g e r i Bangs, American naturalist. July 1898. 32 : 500. (Okak, Labrador)

Skull broad and short, its greatest length about 200 (8). (s o r n b ó r g e r i; name from that of J. D. Sornborger)

The Labrador black bear, known only from the skull, is common throughout Labrador north of the tree limit.

A large bear related to the grizzlies (perhaps U r s u s r i c h a r d s o n i) probably occurs on the barrens of interior Labrador. The species has not yet been determined.

Order **Insectivora** *Insect-eaters*

Canine teeth present but usually not conspicuously developed; cheek teeth formed for chopping; toes provided with claws; *brain small.* (*Species occurring within our limits mostly very small, the largest seldom reaching* 200 (8) *in length; eyes small or rudimentary; fur distinctly modified for an underground life.*) (Insectivorā; N. Lat., insect eaters)

The American insectivores are readily distinguished among the orders of mammals occurring in North America by their small size, small or rudimentary eyes, soft dense fur, many-pointed cheek teeth, and general modification for an underground life. The order is widely distributed in both hemispheres, but is absent in Australia; and in South America is at present known from the extreme northwest only. Two of the nine families into which the order is usually divided occur in North America, and both of these are found within our limits.

FAMILIES OF INSECTIVORA

Fore feet highly modified for digging; external ear absent (moles).. Talpidae
Fore feet not modified for digging; external ear present (shrews).. Soricidae

Family **Talpidae** *Moles*

Body thick, stout and clumsy, without distinct neck; eyes rudimentary or concealed; *no external ear; front feet very large, the nearly circular palm held edgewise;* fur very soft and velvety. (Tálpidae; from genus Talpa)

Moles are found throughout the northern hemisphere except in the extreme north. Eight or more genera are known, five of which occur in North America. Three of these are found within our limits. They are all members of the subfamily Talpinae.

GENERA OF TALPIDAE

Tip of muzzle with a fringe of fleshy projections; tail long...... Condylura
Tip of muzzle without fleshy projections; tail short.
Teeth 36; tail slender, nearly naked........ Scalops
Teeth 44; tail thick, very hairy........ Parascalops

Genus **Condylura** Illiger

1811 Condylura Illiger, Prodr. syst. mamm. et avium, p. 125. (Type Sorex cristatus Linnaeus)

Teeth 44; nostrils at tip of *conspicuously fringed muzzle; tail nearly as long as body,* densely haired. (Condylúra; Gk., knotted tail)

The genus Condylura is confined to eastern North America. Only one species is known.

Condylura cristata (Linnaeus) *Star-nosed mole*

1758 Sorex cristatus Linnaeus, Systema naturae. ed. 10. 1:53. (Pennsylvania)
1819 Condylura cristata Desmarest, Journal de physique. 89:230.
1896 Condylura cristata True, Proc. U. S. national museum. 19:78.

Dusky brown, paler and grayer below. Total length, 170 ($6\frac{3}{4}$); tail vertebrae, 72 ($2\frac{7}{8}$); hind foot, 27 ($1\frac{1}{16}$). (cristáta; Lat., crested)

The star-nosed mole inhabits wet places in the boreal and transition zones of eastern North America. Its northward range is more extensive than that of any other American species.

Genus **Scalops** Illiger

1811 Scalops Illiger, Prodr. syst. mamm. et avium, p. 126. Type Sorex aquaticus Linnaeus.

Teeth 36; nostrils on upper side of simple muzzle; *tail short, not thickened, nearly naked.* (Scálops; Gk., a mole)

The genus Scalops is confined to eastern North America. It contains five or six forms whose interrelationships are not fully understood. Only one of these occurs within our limits.

Scalops aquaticus (Linnaeus) *Naked-tailed mole*

1758 Sorex aquaticus Linnaeus, Systema naturae. ed. 10. 1:53. (Eastern United States)
1825 Scalops aquaticus F. Cuvier, Dents des mammifères, p. 251.
1896 Scalops aquaticus True, Proc. U. S. national museum. 19:19.

Light, glossy slate-brown, often tinged with rusty; tail whitish. Total length, 162 ($6\frac{3}{8}$); tail vertebrae, 27 ($1\frac{1}{16}$); hind foot, 16.5 ($\frac{5}{8}$). (aquáticus; from Lat., aquatic)

The naked-tailed mole inhabits dry sandy soil in the eastern United States and southern Canada from the northern limits of the transition zone southward. The form found within our limits is the typical subspecies, S. aquaticus aquaticus.

Genus **Parascalops** True

1894 Parascalops True, Diagnoses of new North American mammals. 26 Ap. 1894. p. 2. (Reprinted: Proc. U. S. national museum. 15 Nov. 1894. 17:242) Type Scalops breweri Bachman.

Teeth 44; nostrils on outer side of simple muzzle; *tail short, thick, densely haired.* (Parascálops; Gk., near to the genus Scalops)

The genus Parascalops is confined to eastern North America. Only one species is known.

Parascalops breweri (Bachman) *Eastern hairy-tailed mole*

1844 Scalops breweri Bachman, Boston jour. nat. hist. 4: 32. ("Island of Marthas Vineyard, Mass." This doubtless an error.)

1895 Parascalops breweri True, Science. n. s. 25 Jan. 1895. 1: 101.

1896 Parascalops breweri True, Proc. U. S. national museum. 19: 68.

Dark lead-gray, seldom if ever tinged with rusty; tail dark. Total length, 147 (5 13/16); tail vertebrae, 30 (1 3/16); hind foot, 19 (3/4). (bréweri; name from that of Thomas Mayo Brewer)

The eastern hairy-tailed mole inhabits dry soil in the boreal and transition zones of the eastern United States and southern Canada.

Family **Soricidae** *Shrews*

Body usually slender and mouse-like, with a distinct neck; eyes well developed but very small; *a distinct external ear; front feet small, not specially modified;* fur only moderately soft and dense. (Sorícidae; from genus Sorex)

The range of the family Soricidae is essentially the same as that of the order Insectivora. 10 or more genera are known, three of which occur in North America. Two of these are found within our limits. Shrews are small animals much like mice in general appearance but readily distinguishable by their pointed snouts and small eyes.

GENERA OF SORICIDAE

Ears completely hidden by the fur; tail scarcely longer than head.. Blarina
Ears distinctly visible; tail much longer than head.................... Sorex

Genus **Blarina** Gray

1838 Blarina Gray, Proc. zool. soc. London. (1837) p. 124. Type Sorex talpoides Gapper=S. brevicaudus Say.

Ears very small, completely hidden by the fur; body stout, somewhat mole-like; *tail scarcely longer than head.* (Blarína; a coined word)

The genus Blarina is peculiar to America. All but one of the 23 known forms are North American or Central American. The exception, B. thomasi Merriam, is the only known South American member of the order Insectivora. Two species only are found within our limits.

SPECIES OF BLARINA

Teeth 32; total length about 120 (4 3/4) (subgenus Blarina).. B. brevicauda
Teeth 30; total length about 75 (3) (subgenus Cryptotis)........ B. parva

Blarina brevicauda (Say) *Large blarina*

1823 Sorex brevicaudus Say, Long's exped. to the Rocky mts. 1: 164. (Near Blair Neb.)

1857 Blarina brevicauda Baird, Mamm. N. Am. p. 42.

1895 Blarina brevicauda Merriam, North American fauna. 31 Dec. 1895 no. 10, p. 10.

Teeth 32; color sooty slate-brown above, more ashy below. *Total length*, 120, ($4\frac{3}{4}$); tail vertebrae, 25 (1); hind foot, 15 ($\frac{9}{16}$). (brevicáuda; Lat., short tail)

The typical form of the large blarina, Blarina brevicauda brevicauda, is one of the most abundant mammals in dry woods and old fields throughout eastern North America, from the lower edge of the upper austral zone north into the boreal zone. In the lower austral zone of the southeastern United States it gives way to a smaller form, B. brevicauda carolinensis (Bachman).

Blarina parva (Say) *Small blarina*

1823 Sorex parvus Say, Long's exped. to the Rocky mts. 1:164. (Near Blair Neb.)

1895 Blarina parva Merriam, North American fauna. 31 Dec. 1895. no. 10, p. 17.

Teeth 30; color brownish above, ashy below. *Total length*, 75 (3); tail vertebrae, 15 ($\frac{9}{16}$); hind foot, 10 ($\frac{3}{8}$). (párva; Lat., small)

The small blarina is common in meadows and old fields throughout the upper austral and lower austral zones in the eastern United States. Its range therefore extends north about to the southern border of New York.

Genus Sorex Linnaeus

1758 Sorex Linnaeus, Systema naturae. ed. 10. 1:53. Type Sorex araneus Linnaeus.

Ears well developed, generally appearing distinctly above the fur; body slender, mouse-like; *tail much longer than head*. (Sórex; Lat., a field mouse)

The genus Sorex is very generally distributed throughout the boreal portion of the northern hemisphere. It probably contains 75 or more species. In America 42 forms are known; of these six occur within our limits.

SPECIES OF SOREX

Total length over 140 ($5\frac{1}{2}$); hind feet conspicuously fringed (subgenus Neosorex) .... S. albibarbis

Total length under 130 ($5\frac{1}{4}$); hind feet not fringed

- Fourth tooth in upper jaw exceedingly minute (almost invisible without aid of lens), closely wedged between well developed third and fifth (subgenus Microsorex) .... S. hoyi
- Fourth tooth in upper jaw well developed (subgenus Sorex)
  - Tail vertebrae about 55 ($2\frac{3}{16}$) .... S. macrurus
  - Tail vertebrae less than 50 (2)
    - Back conspicuously blackish .... S. richardsoni

Back not conspicuously blackish
Hind foot about 14 (9/16); general color smoky slate-color throughout .... S. fumeus
Hind foot about 12 (1/2); back clear brown, belly whitish gray.. S. personatus

Sorex albibarbis (Cope) *Eastern marsh shrew*

1862 Neosorex albibarbis Cope, Proc. acad. nat. sci. Philadelphia, p. 188. (Profile lake, N. H.)

1892 Sorex albibarbis Merriam, Proc. biolog. soc. Washington. 7:25.

1895 Sorex albibarbis Miller, North American fauna. 31 Dec. 1895. no. 10, p. 46.

Upper parts blackish slate with a slight hoary cast; chin and throat grayish white; rest of lower parts dusky. Total length, 155 (6 1/8); *tail vertebrae*, 70 (2 3/4); hind foot, 19 (3/4). (albibárbis; Lat., white beard)

The marsh shrew inhabits marshes and the banks of watercourses in the boreal zone of eastern North America south in the mountains at least to Pennsylvania and probably farther.

Sorex hoyi Baird *Hoy's shrew*

1857 Sorex hoyi Baird, Mamm. N. Am. p. 32 (Racine Wis.)

1895 Sorex hoyi Miller, North American fauna. 31 Dec. 1895. no. 10, p. 43.

Upper parts sepia-brown; lower parts whitish gray *usually washed with yellowish on chest.* Total length, 90 (3 9/16); tail vertebrae, 32 (1 1/4); hind foot, 10 (3/8). (hóyi; name from that of P. R. Hoy)

Hoy's shrew, a little known animal, inhabits open fields, plains and clearings in the boreal zone and upper part of the transition zone from British Columbia to Nova Scotia, south to Wisconsin and northern New York.

Sorex macrurus Batchelder *Big-tailed shrew*

1896 Sorex macrurus Batchelder, Proc. biolog. soc. Washington. 8 Dec. 1896, 10:133. (Beedes, Essex co. N. Y.)

Upper parts blackish slaty, lower parts dark smoke gray. Total length, 125 (5); *tail vertebrae*, 57 (2 1/4); hind foot, 15 (9/16). (macrúrus; Gk., big tail)

The big-tailed shrew is known from the eastern Adirondacks and the Catskills only. Thus far only 10 specimens have been recorded.

Sorex richardsoni Bachman *Richardson's shrew*

1857 Sorex richardsoni Bachman, Jour. acad. nat. sci. Philadelphia. 7: 383. (Probably from plains of Saskatchewan)

1895 Sorex richardsoni Miller, North American fauna. 31 Dec. 1895. no. 10, p. 48.

Back very dark (almost blackish) brown, without slaty tinge; *sides* dull yellowish brown; *under parts* grayish, washed with chestnut. Total length,

112 ($4\frac{3}{8}$); tail vertebrae, 40 ($1\frac{9}{16}$); hind foot, 14 ($\frac{9}{16}$). (richardsóni; name from that of John Richardson)

Richardson's shrew, an imperfectly known species, occurs in the boreal zone of Saskatchewan, northern Minnesota, the north shore of Lake Superior and in New Brunswick[1].

Sorex fumeus Miller *Smoky shrew*

1895 Sorex fumeus Miller, North American fauna. no. 10, p 50. (Peterboro, Madison co. N. Y.)

Smoky slate color, slightly paler below. Total length, 115 ($4\frac{1}{2}$); tail vertebrae, 45 ($1\frac{3}{4}$); hind foot, 14 ($\frac{9}{16}$). (fúmeus; Lat., smoky)

The smoky shrew inhabits the forests of the boreal zone and upper part of the transition zone in eastern North America, south into the southern Alleghanies.

Sorex personatus Geoffroy St Hilaire *Maskea shrew*

Clear brown (*sepia or drab*) *above*, whitish gray below. Total length, 90 ($3\frac{1}{2}$) to 110 ($4\frac{5}{16}$); hind foot, 13 ($\frac{17}{32}$) or less. (personátus; Lat., masked)

The masked shrew occurs throughout the greater part of boreal North America, and in cold situations even in the upper austral zone. It is divisible into several races, three of which occur within our limits.

SUBSPECIES OF SOREX PERSONATUS

Total length about 95 ($3\frac{3}{4}$) .... S. personatus lesueuri
Total length about 105 ($4\frac{1}{8}$)
Back sepia brown at all seasons........... S. personatus personatus
Back light (broccoli) brown in summer, drab
gray in winter .... S. personatus miscix

Sorex personatus personatus I. Geoffroy St Hilaire *Northern masked shrew*

1827 Sorex personatus E. Geoffroy St Hilaire, Mem. du muséum, d' hist. nat. Paris. 15:122. (Eastern United States, probably New York)

1895 Sorex personatus Miller, North American fauna. 31 Dec. 1895. no. 10, p. 53.

Upper parts sepia brown; under parts whitish gray. Total length, 105 ($4\frac{1}{8}$); tail vertebrae, 40 ($1\frac{9}{16}$); hind foot, 12 ($\frac{1}{2}$). (personátus; Lat., masked)

The northern masked shrew is abundant in a great variety of situations throughout the transition zone and Canadian zone of the eastern United States and eastern Canada.

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1 For occurrence of Sorex richardsoni in New Brunswick see Cox, Canadian record of science. Ap. 1896. 7:117-18.

Sorex personatus lesueuri (Duvernoy) *Southern masked shrew*

1842 Amphisorex lesueuri Duvernoy, Magasin de zoologie, mamm. Nov. 1848. p. 33. (Wabash river, Indiana)

1895 [Sorex personatus] lesueuri Merriam, North American fauna. 31 Dec. 1895. no. 10, p. 61.

Color as in S. personatus personatus; size smaller. Total length, 90 ($3\frac{1}{2}$); tail vertebrae, 33 ($\frac{5}{16}$); hind foot, 10.5 ($\frac{6\frac{1}{2}}{16}$). (lesúeuri; name from that of Lesueur)

The southern masked shrew is confined to the cool, boreal sphagnum bogs of the upper austral zone. It is the smallest of our mammals, and at present very rare in collections.

Sorex personatus miscix Bangs *Labrador masked shrew*

1899 Sorex personatus miscix Bangs, Proc. New England zool. club. 28 Feb. 1899. 1: 15. (Black bay, Labrador)

Upper parts in winter drab gray, in summer very light (broccoli) brown; under parts pale gray. Total length, 102 ($4\frac{1}{16}$); tail vertebrae, 43 ($1\frac{3}{4}$); hind foot, 13 ($\frac{17}{32}$) (míscix; Lat., changeable)

The Labrador masked shrew is at present known from Black bay, Labrador only.

Order **Chiroptera** *Bats*

Fore limbs greatly developed, the elongated fingers *supporting a membrane by means of which true flight is performed.* (Chiróptera; Gk., hand-wings)

The bats, though most numerous in the tropics, are almost universally distributed. The order contains two suborders, one the Megachiroptera (flying foxes) peculiar to the old world, the other, the Microchiroptera, (true bats) with the same range as the order. The Microchiroptera are usually divided into five families, but this number will probably be greatly increased. Only one family, the Vespertilionidae, occurs in northeastern North America.

Family **Vespertilionidae** *Typical bats*

Tail included in membrane nearly or quite to tip; nose without leaf-like fleshy outgrowths. (Vespertiliónidae; from genus Vespertilio)

The family Vespertilionidae has essentially the same range as the order Chiroptera. It contains many genera, 12 of which occur in North America. Six are found within our limits; all of these are members of the subfamily Vespertilionínae, or typical bats with simple nostrils and separate ears.

GENERA OF VESPERTILIONIDAE

Membrane between legs completely furred above.......... Lasiurus, p. 147
Membrane between legs not completely furred above
  Fur blackish, frosted with white................ Lasionycteris, p. 149
  Fur not blackish, frosted with white
    Total length over 100 (4).................... Vespertilio, p. 151
    Total length under 100 (4)
      Individual hairs on back with three distinct color bands.................. Pipistrellus, p. 150
      Individual hairs on back with less than three distinct color bands
        Upper front teeth 2................ Nycticeius, p. 148
        Upper front teeth 4...................... Myotis, p. 148

Genus Lasiurus Gray

1831 Lasiurus Gray, Zoological miscellany. no. 1, p. 38 (based on the American hairy-tailed bats).

Teeth 32; only two front teeth in upper jaw between canines; *back of membrane between legs densely furred;* ears short and round. (Lasiúrus; Gk., silk tail)

The genus Lasiurus is peculiar to America, where it is represented by half a dozen or more species. Two of these occur within our limits.

SPECIES OF LASIURUS

Total length 135 (5¼); general color hoary; rim of ear dark... L. cinereus
Total length 110 (4¼); general color reddish; rim of ear light... L. borealis

Lasiurus cinereus (Beauvois) *Hoary bat*

1796 Vespertilio linereus (Obvious misprint for cinereus) Beauvois, Catalogue Peale's museum. Philadelphia. p. 14. (Philadelphia Pa.)
1864 Lasiurus cinereus H. Allen, Monogr., bats N. Am. p. 21.
1897 Lasiurus cinereus Miller, North American fauna. 16 Oct. 1897. no. 13, p. 112.

General color a mixture of light yellowish brown, deep umber brown, and white. Total length, 135 (5¼); tail vertebrae, 50 (2); forearm, 40 (2⅝). (cinéreus; Lat., gray)

The hoary bat breeds throughout the forests of the boreal zone of North America. In autumn and winter it migrates far to the southward of its breeding range.

Lasiurus borealis (Müller) *Red bat*

1776 Vespertilio borealis Müller, Natursyst. suppl.-u. regist.-band. p. 21. (New York)
1897 Lasiurus borealis Miller, North American fauna. 13 Oct. 1897. no. 13, p. 105.

General color varying from rufous red to yellowish gray; *a white spot at shoulder*, som etims connected with its fellow by a white chest band. Total length, 110 ($4\frac{1}{4}$); tail vertebrae, 50 (2); forearm, 40 ($1\frac{9}{16}$). (boreális; Lat., northern)

The red bat occurs in a great variety of situations throughout most of North America. It is divisible into several geographic races. The typical form, L. borealis borealis is the only one that occurs within our limits.

Genus **Nycticeius** Rafinesque

1819 Nycticeius Rafinesque, Journal de physique. 88 : 417. Type N. humeralis Rafinesque.

Teeth 30; only two front teeth in upper jaw between canines; back of membrane between legs furred at extreme base only; ears short, obtusely pointed. (Nycticéius; Gk., night being).

Nycticeius is peculiar to North America, though closely related to an old world genus (Scotophilus). It is represented by one species only, a small but thickset bat with broad muzzle and blunt ears.

Nycticeius humeralis Rafinesque *Rafinesque's bat*

1818 Vespertilio humeralis Rafinesque, American monthly magazine. 3: 445. (Kentucky)

1819 Nycticeius humeralis Rafinesque, Journal de physique. 88 : 417.

1897 Nycticeius humeralis Miller, North American fauna. 16 Oct. 1897. no. 13, p. 118.

Dull umber brown above, paler below. Total length 90 ($3\frac{1}{2}$); tail vertebrae, 36 ($1\frac{7}{16}$); forearm, 36 ($1\frac{7}{16}$). (humerális; Lat., humeral)

Rafinesque's bat inhabits the austral zones of the eastern United States. At present it has not been found north of Carlisle Pa.

Genus **Myotis** Kaup

1829 Myotis Kaup, Skizzirte Entw.-gesch. u. natürl. syst. d. Europ. Thierw. 1:106. Type Vespertilio murinus Schreber = V. myotis Bechstein.

Teeth 38; two pairs of front teeth in upper jaw between canines; back of membrane between legs naked except at extreme base. (Myótis; Gk., mouse ear)

The genus Myotis is very widely distributed in both eastern and western hemispheres. The species are still imperfectly known. In North America 16 forms are known, but only two of these occur within our limits. These are small delicately formed bats with slender muzzles and narrow ears.

SPECIES OF MYOTIS

Ear, when laid forward, reaching considerably beyond tip of muzzle.. M. subulatus
Ear, when laid forward, reaching about to tip of muzzle...... M. lucifugus

Myotis subulatus (Say) *Say's bat*

1823 ?Vespertilio subulatus Say, Long's exped. to Rocky mts. 2:65. (Arkansas river, near La Junta Col.)

1864 Vespertilio subulatus H. Allen, Monogr, bats. N. Am. p. 51. (Eastern United States)

1897 Myotis subulatus Miller, North American fauna. 16 Oct. 1897. no. 13, p. 75.

Dull brown, slightly paler and more yellowish below; *ear reaching considerably beyond* tip of nose when laid forward. Total length, 85 (3⅜); tail vertebrae, 38 (1½); forearm, 35 (1⅜). (subulátus; Lat., awl-shaped)

Say's bat is locally common throughout eastern North America, south into the upper austral zone. The details of its distribution are imperfectly known. The form found within our limits is M. subulatus subulatus.

Myotis lucifugus (Le Conte) *Little brown bat*

1831 Vespertilio lucifugus Le Conte, Mc Murtries's Cuvier, Animal kingdom, 1, append. p. 431. (Southern Georgia)

1897 Myotis lucifugus Miller, North America fauna. 16 Oct. 1897. no. 13, p. 59.

Dull brown, slightly paler and more yellowish below; *ear reaching barely to nostril* when laid forward. Total length, 85 (3⅜); tail vertebrae, 38 (1½); forearm, 38 (1½.) (lucífugus; Lat., light-fleeing)

The little brown bat is abundant throughout eastern North America, south to the gulf coast. Within our limits it is represented by the typical race, M. lucifugus lucifugus.

Genus Lasionycteris Peters

1865 Lasionycteris Peters, Monatsber. K. Preuss. akad. wissensch. Berlin. p. 648. Type Vespertilio noctivagans Le Conte.

Teeth 36; two pairs of front teeth in upper jaw between canines; *back of membrane between legs furred to about middle.* (Lasionýcteris; Gk., silk bat)

The genus Lasionycteris is peculiar to North America. It contains one species only.

Lasionycteris noctivagans (Le Conte) *Silvery bat*

1831 Vespertilio noctivagans Le Conte, McMurtries' Cuvier, Animal kingdom. June 1831. Append. p. 431. (Eastern United States)

1865 Lasionycteris noctivagans Peters, Monatsber. K. Preuss. akad. wissensch., Berlin. p. 648.

1897 Lasionycteris noctivagans Miller, North American fauna. 16 Oct. 1897. no. 13, p. 86.

Blackish, frosted with white. Total length, 100 (4); tail vertebrae, 40 ($1\frac{9}{16}$); forearm, 40 ($1\frac{9}{16}$). (noctívagans; Lat., night wandering)

The silvery bat is a common species in eastern North America. It is apparently most numerous in the boreal and transition zones.

Genus **Pipistrellus** Kaup

1829 Pipistrellus Kaup, Skizzirte Entwick.-gesch. u. natürl. syst. d. Europ. Thierw. Th. 1, p. 98. Type Vespertilio pipistrellus. Schreber.

Teeth 34; two pairs of front teeth in upper jaw between canines; back of membrane between legs thinly haired on basal third. (Pipistréllus; N. Lat., a pipistrelle)

The genus Pipistrellus is widely distributed in both old and new worlds. It contains numerous species, only three of which are American. One of these occurs within our limits.

Pipistrellus subflavus (F. Cuvier) *American pipistrelle*

Hairs on back with three distinct color bands. Total length, 85 ($3\frac{3}{8}$); tail vertebrae, 40 ($1\frac{9}{16}$); forearm, 35 ($1\frac{3}{8}$). (subflávus; Lat., yellowish.)

The pipistrelle inhabits the eastern United States north to Lake George, New York. It is one of the most abundant bats throughout the austral zones. It is divisible into two subspecies.

SUBSPECIES OF PIPISTRELLUS SUBFLAVUS

General color light yellowish brown .... P. subflavus subflavus
General color drab brown .... P. subflavus obscurus

Pipistrellus subflavus subflavus (F. Cuvier) *Southeastern pipistrelle*

1832 Vespertilio subflavus F. Cuvier, Nouv. Ann. mus. d'hist. nat. Paris. p. 17. (Eastern United States, probably Georgia)

1897 Pipistrellus subflavus Miller, North American fauna. 16 Oct. 1897. no. 13, p. 90.

General color light yellowish brown, the individual hairs on back deep plumbeous at base, yellowish brown at middle and dark brown at tip. (subflávus; Lat., yellowish)

The southeastern pipistrelle is very abundant throughout the austral zones of the eastern United States, north to the lower Hudson valley.

Pipistrellus subflavus obscurus Miller *Northeastern pipistrelle*

1897 Pipistrellus subflavus obscurus Miller, North American fauna. 16 Oct. 1897. no. 13, p. 93. (Lake George, New York)

General color dull, pale, drab brown. (obscúrus; Lat., dusky)

The northeastern pipistrelle is at present known from one locality only, Lake George, Warren co. N. Y.

Genus **Vespertilio** Linnaeus

1758 Vespertilio Linnaeus, Systema naturae. ed. 10. 1:31. Type V. murinus, Linnaeus.

Teeth 32; two pairs of front teeth in upper jaw between canines; back of membrane between legs naked except for a sprinkling of fine hairs on basal fourth. (Vespertílio; Lat., a bat)

The genus Vespertilio is widely distributed in both hemispheres, but the species are very imperfectly known. Only one occurs in North America.

Vespertilio fuscus Beauvois *Big brown bat*

1796 Vespertilio fuscus Beauvois, Catalogue Peale's museum. Philadelphia. p. 18. (Philadelphia Pa.)

1897 Vespertilio fuscus Miller, North American fauna. 16 Oct. 1897, no. 13, p. 96.

Sepia brown, paler below. Total length, 110 ($4\frac{3}{8}$); tail vertebrae, 45 ($1\frac{3}{4}$); forearm, 45 ($1\frac{3}{4}$). (fuscus; Lat., dark)

The big brown bat occurs throughout Mexico, the United States and southern Canada north to the lower edge of the boreal zone. It is divisible into several races, of which the typical, V. fuscus fuscus, is abundant in eastern North America.

CORRECTIONS

Corrections of the names of two of the mammals occurring in eastern North America have been published[1] too late to be inserted in the body of this paper. They are as follows:

The house rat (p. 95) should be Mus norvegicus Erxleben, Syst. regn. anim. p. 381. 1777.

The northeastern fox squirrel (p. 87) should be Sciurus ludovicianus neglectus (Gray) (Macroxus neglectus Gray, Ann. and Mag. nat. hist. 1867, 3d ser. 20: 425. Sciurus ludovicianus neglectus Nelson, Proc. biolog. soc. Washington 31 Oct. 1900. 13: 170)

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1 Proc. biol. soc. Washington, 31 Oct. 1900. 13 : 167, 169-70

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The superior figures tell the exact place on the page in ninths; e. g. 62^{3} means page 62, beginning in the third ninth of the page, i. e. about one third of the way down. Synonyms are printed in italics.

(Pages 161–62 were bulletin cover pages)

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PALEONTOLOGIC PAPERS

BY

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State paleontologist

GEORGE B. SIMPSON AND FREDERIC B. LOOMIS PH. D.

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1900

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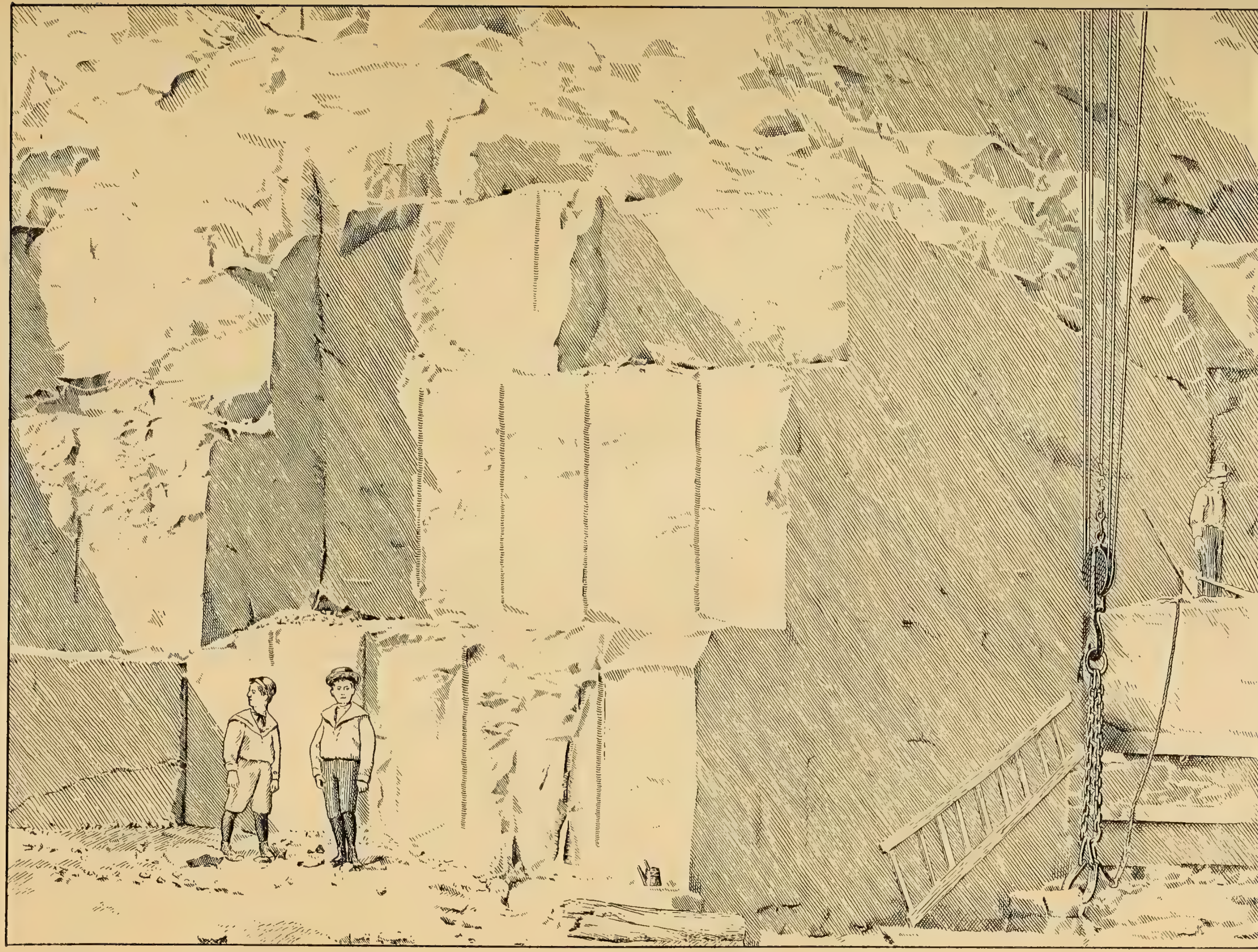


Oneonta sandstone in the Clarke Co.'s quarry, Oxford N. Y. 18 foot layer showing vertical *Orthoceras* near the base

A REMARKABLE OCCURRENCE OF ORTHOCERAS IN THE ONEONTA BEDS OF THE CHENANGO VALLEY, N. Y.

BY JOHN M. CLARKE

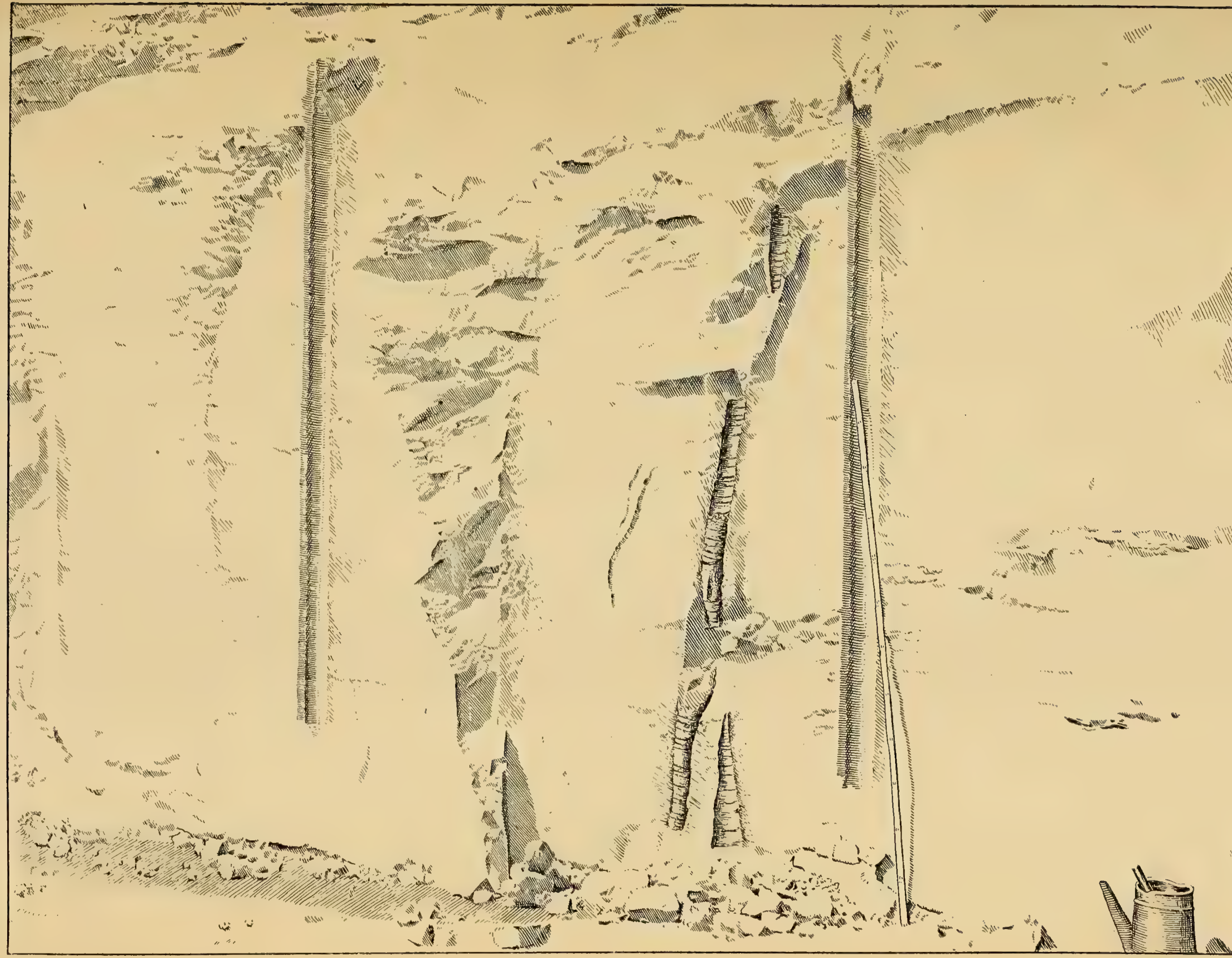
(Plates 1–4)

At Oxford in the valley of the Chenango river in southern central New York are the extensive bluestone quarries of the F. G. Clarke Co. These quarries lie in the westward extension of the formation termed by Vanuxem the Oneonta beds. I have shown on previous occasions that these Oneonta beds represent in the Chenango valley region a peculiarly local development of the later deposits made during the period of time known as the Portage age. They are underlaid by the lower beds of the Ithaca stage, bearing an abundant marine fauna very closely allied in specific traits to the fauna of the Hamilton shales beneath. The Oneonta deposits were evidently laid down in a shallow or receding sea or perhaps, speaking with more precision, in an estuary while shut off from the open sea and freely receiving terrestrial drainage. The deposits contain no forms of life similar to those of the upper beds of the Ithaca formation with which they are apparently stratigraphically continuous and which bound them on the west. Their strata consist for the most part of schistose sands here and there interstratified with fine-grained argillaceous shales carrying in places considerable calcareous matter. The deposits are several hundred feet in thickness in this section, and are often highly colored by the green and red tints of iron oxids, in which respect they are not unlike some of the sands of the Catskill formation. With our present knowledge we interpret the Oneonta sedimentation as of similar origin to that of the Catskill and the precursor or the introduction of the latter in the meridian of the Chenango valley. Here the Chemung beds, carrying a marine fauna, extend over the Oneonta sediments and separate them from the Catskill above, but, passing eastward into Delaware co., the Chemung strata finally dis-

appear or become indeterminate, and the Oneonta sedimentation is continued without interruption directly into the Catskill, the entire series of beds representing there a continuance of similar estuarine conditions. Organic remains in these Oneonta deposits are by no means of common occurrence. Fish remains are sometimes found in most excellent preservation, and some of these have been described, but these nectonic animals are not necessarily to be regarded as proper members of the fauna of this estuarine province. Large quantities of terrestrial driftwood, often forming handsome specimens of Lepidodendron and fern fronds, have been brought in by the surface drainage, and over the surface of the soft shales one may find traces of annelid tracks, crustacean trails and impressions of ostracodes. The most characteristic fossil of the entire series however is the Cypricardites catskillensis, of Vanuxem, the Amnigenia catskillensis, of Hall. This large Unio-like shell, showing in its form and hinge structure its relation to its fresh-water descendants, abounds in some places in the Oneonta beds, particularly in the outcrops about Oxford.

In the Clarke quarry at Oxford the principal bluestone layer is a compact, fine-grained, greenish gray sandstone lying at the base of the opening, having a thickness of about 25 feet and known by the quarrymen as "liver rock", an expression equivalent to the better known term, freestone. Below this layer the quarrymen at times expose a similar sandstone having a thickness of about 5 feet which, though not always accessible, is regarded as of excellent quality for commercial purposes. Some months ago, by the favor of E. E. Davis of Norwich, my attention was called to the fact that this rock, which is really seldom exposed, is crossed vertically by regular specimens of Orthoceras standing with the apexes downward and traversing the entire thickness of the layer. The specimens brought to me at that time had been dislodged from the matrix and showed that the shell had been replaced entirely by the sand and all its cavities filled in the same way by the sediment. The cones also had been more or less compressed laterally and yet preserved the evidence

Plate 2



Nearer view of the basal layer shown in plate 1. The staff with upper end resting on wall of drill hole is 3 feet long and indicates the length of the longer *Orthoceras*. A second individual is seen at the base of the layer

of septation and showed the position and form of the siphuncle. On examining this stratum in place I have found that these shells are seldom deflected from the vertical; and they are exposed on any broken face of the rock in such a way that the quarrymen have long designated the stratum as the "core bed", speaking of the fossils themselves as "cores", an expressive term in view of the fact that in most cases they have about the same size as the drill holes, which also penetrate the bed vertically. One is often forcibly impressed with the appearance of a fragment of the stratum bearing on its face alternate drill holes and casts of Orthoceras. These shells appear to have made no interruption in the sedimentation. The straticular lines run horizontally to them, may often be seen crossing them, or if not crossing they are not deflected or disturbed about them. The number of shells in this particular stratum is incalculable. On the surface of a stone measuring 3 feet by 18 inches I have counted the transverse sections of 15 individuals, this but an average instance. In the stratum overlying the "liver rock", these shells are less numerous but are present, and one of our photographs shows one about 4 feet in length in the lower bench of this bed.

It is not only in the quarry of which I speak that these Orthoceras-bearing strata have been observed. On the east side of the Chenango valley at Oxford they occur in small quarries situated from three fourths to one mile away from the Clarke quarry, and likewise in the old Miller quarry (controlled by the Clarke Co.) at Coventry or South Oxford, 2 miles due south of Oxford. The dip of the rocks throughout this region is very slight, and, as the strata at Coventry are pretty high, I am disposed to believe that the appearance of this peculiar rock at the latter place is not a reappearance of the same stratum, but indicates a recurrence of the same phenomenon at a subsequent period. The rock at Coventry differs from that at Oxford in this respect. Instead of being a compact sandstone, the layer is schistose and is taken out for unsawn flagstone. The individuals of Orthoceras are seen penetrating successive layers of flags, and on the sedimentation surface of these flags the

transverse sections of the Orthoceras appear as circular or oval discolorations elevated or depressed and are known to the quarry men as "knots." In no instance have I noticed any marked deviation in the position of these long, straight cephalopod shells from the vertical, nor are they oriented otherwise than with the apexes down and apertures up.

We have then here layers of sand, deposited in a shallow, retired sea or arm of the sea at a depth and under conditions extremely unfavorable for the development and growth of true marine life, crowded with innumerable thousands of these cephalopods in this most peculiar and unexpected attitude. As to the cause of this occurrence, one fact seems perfectly clear, that these shells have been borne in by the waves from deeper waters, as it is well established that Orthoceras, like most of its heavily shelled allies, was a benthonic animal. These remains must also have been floated in as dead shells, but their position with the apex down is not easy to account for unless we conceive that the early chambers had been broken into and more or less filled with mud or sand. As to the source whence they came, it may be said that, though these fossils have not clearly retained specific characters, an Orthoceras of similar large size and general proportions is occasionally found in the fauna of the Ithaca group which occupied the province immediately to the west during the deposition of the Oneonta beds.

In the discussion of this problem before the geologic section of the American association at its Columbus meeting (1899) it was suggested that a sudden incursion of fresh water from the continental drainage way into the marine province occupied by these Orthocerata would be a sufficient cause for the sudden and immediate extinction of their life. I should regard this as a probable explanation of that general and widespread destruction. Such a cause would have annihilated all associated marine life, and it is evident that the Orthocerata have been carried well away from their habitat by flotation after death. With the apical chambers of the shells weighted with

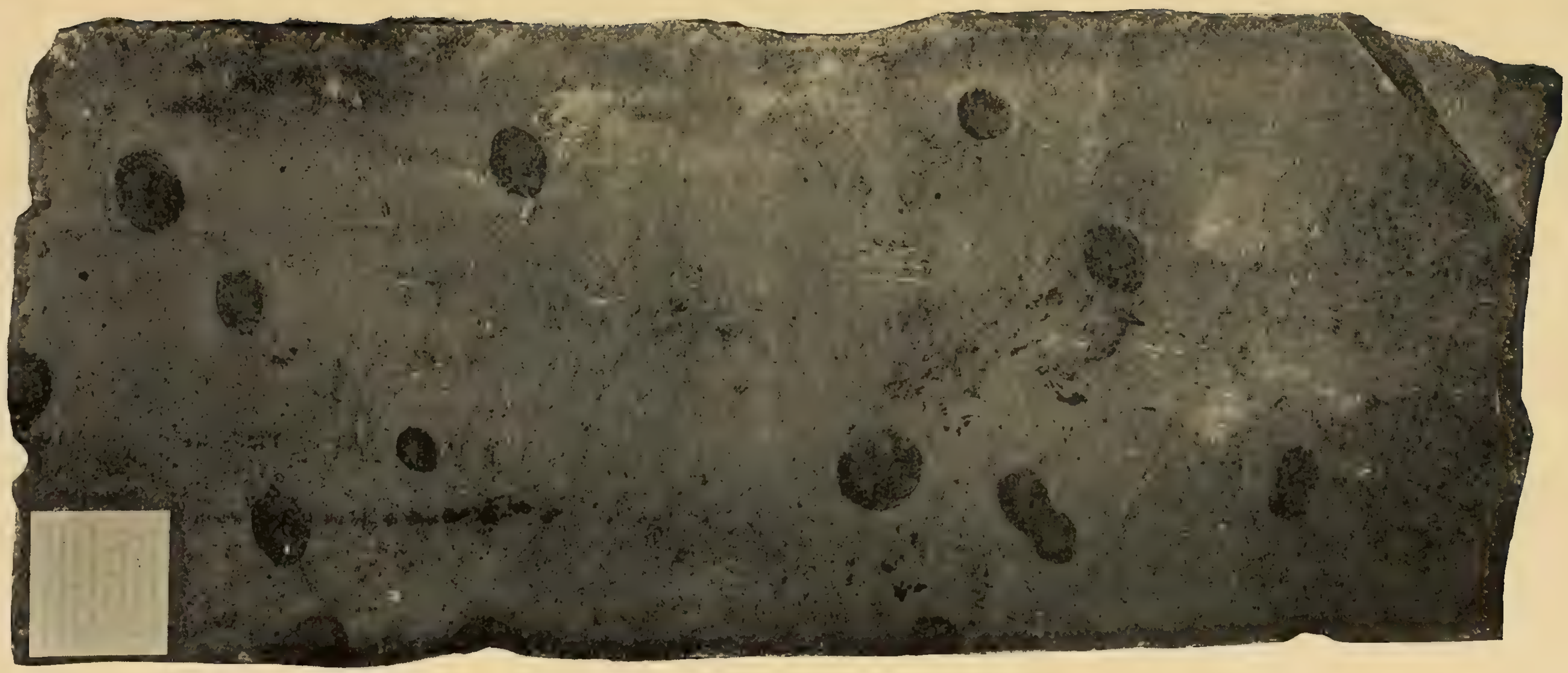
Plate 3

A block fallen from the rock wall in an inverted position. The *Orthocerata* show the septa directed downward or toward the quarry floor, and one of them shows the position of the siphuncle

Plate 3a

A fallen block of sandstone showing 3 *Orthocerata* and a drill hole

Plate 4



A slab of flag stone from the Clarke Co.'s quarry at Coventry, showing horizontal sections of 15 shells of *Orthoceras*. Size of slab 40 x 18 inches (N. Y. state museum)

mud and the later chambers filled with gases of decomposition, the erect position of the shells, maintained continuously while the sedimentation went on about them, would naturally be assumed.

In the flagstones appearing throughout the quarry region in the vicinity of West Hurley, Ulster co., evidence of similar occurrences of vertical Orthoceras has been observed. Doubtless the greater part of the entire mass of these flagstones, which according to the estimate made by N. H. Darton are not less than 4000 feet thick, represents physical conditions quite similar to those evident in the rocks of the Chenango valley, conditions which here are completed and terminated only with the termination of the Catskill formation. Some of the evidences of the vertical Orthoceras from these rocks are conclusive, though in respect to abundance and mode of preservation they are less impressive than the occurrence at Oxford. In association with these organic remains are, however, often found formations of similar appearance, likewise crossing the strata vertically, frequently of small size, and when the rock is schistose, showing concavities on one side and convexities on the other side of the slabs. The majority of these are doubtless of mechanical origin, perhaps in part representing vertical tubules or vertical disturbances of straticulation by the bubbling of confined gases or air up through the sediments.

PAROPSONEMA CRYPTOPHYA

A peculiar echinoderm from the Intumescens-zone (Portage beds) of western New York

BY JOHN M. CLARKE

(Plates 5-9)

While prosecuting paleontologic work in the Portage formation of western New York during the season of 1895, D. D. Luther brought to light a number of interesting hexactinellid sponges or Dictyospongidae at the horizon of the Portage sandstones in the Tannery gully at Naples N. Y. These proved to belong largely to the genus Hydnoceras and constitute the first evidence obtained of the existence of such bodies in this formation. Among them was a single incomplete fragment, showing a radial surface structure modified by fine, interrupted cross-lines, that give the surface of the body a plaited aspect suggestive of minute basket work. The body, through incompleteness and obscure retention, failed to explain itself or even suggest its true nature, though it was clearly evident that it had no relation to the sponges with which it was found. In the season of 1897, Mr Luther obtained from a loose slab of Portage sandstone in the vicinity of the former locality several specimens of this fossil in so complete a state as to justify the inference that all the parts capable of preservation in such sediments are here retained. Since then he has been successsful in locating the stratum containing the fossil. These specimens are in different conditions of excellence; one has suffered little modification in outline, another is but slightly irregular in its periphery, and of the rest only portions greater or less are preserved.

The fossil is discoid and of quite regularly elliptic outline; the one best preserved has a length of 190 mm and a width of 160 mm, the original shell being thus of no inconsiderable size. The thickness of these large disks is very slight. We shall presently observe the total difference in the aspect of the upper and lower surfaces, and yet some of the examples show that between these surfaces there was but a very narrow space. In the specimen represented by the two figures, plates 6 and 7, which are

opposite faces, the space intervening had not more than the thickness of a piece of blotting paper and had been filled, not with matrix or any ancient deposit, but with a comparatively recent, discontinuous deposition of infiltrated, amorphous calcite of the same character as that elsewhere observed on more exposed partings of the matrix. In another specimen this interval is greater, though variable, and is seen to be filled with the sandy matrix. It is to be assumed that such disk-shaped bodies in rocks of this character under no little vertical pressure from superjacent sediments, must have, unless highly resistant, been compressed to the almost complete extinction of the interior space; and, on investigation of these structures, it seems that the original matter of the fossils, so far from being capable of withstanding high pressure, probably yielded to very slight strains.

One of the two sides is smooth, that is to say, devoid of regular structure or intimate detail. Its surface is however wrinkled and puckered. Where this character is best manifested it is clear that the largest of the wrinkles as well as the vast number of very minute ones are the outcome of compression; the former are pinched up into one or two prominent folds, the others lie over the surface principally of the median portion. This median part of the fossil evinces by these indexes the greatest compression. More regularity marks the series of wrinkles which depart from the central area toward the periphery, ramifying, inosculating and spreading outward but becoming extinct before the actual margin of the disk is reached. In some cases traces of finer, direct radial striae are visible over the smooth peripheral border, but these are not always clear. Such is the aspect of the surface which for convenience and perhaps with propriety we may term the ventral; but it is the aspect shown by the removal from this surface of the opposite side of the disk, and doubtless its contour is that of the interior side of this ventral shell. Let us reverse, therefore, the contour as described and we shall have the aspect of the exterior ventral surface, on which there will be the casual wrinkles as before, but the radiating and true structural features will be anastomosing grooves and channels,

strikingly similar to those found on the ventral side of any Scutella.

The opposite or dorsal side likewise gives evidence of these structural channels. I am satisfied however, that these do not appertain to this surface but have been developed in such specimens by compression against the ventral surface; for where these channels are most strongly developed they correspond in shape and position on the two sides, as is seen by laying one side on the other, as it was when they were found in the rock; furthermore, specimens which have been somewhat obliquely compressed, or lodged in the matrix at such an angle that compression failed to bring the opposite faces into contact do not bear these markings. The leading character of this dorsal surface, however, consists of a great number of radial lines departing from the central point of the disk. We observe, first, that these radial lines about the center have somewhat the appearance of broad cords closely knotted at regular intervals. We may conceive of two such knotted cords lying side by side, the knots of one fitting into the intervals of the other, each pair very gradually widening outward from the center and each separated from the next pair by a smooth, ligulate area not wider than the cords. Or these radii may be likened to a series of braids widening outward. The number of such braids meeting at or departing from the center has not been definitely determined, as in the most complete of the specimens they are not sufficiently distinct to permit enumeration. They are, however, very numerous. Where most clearly retained there are about 25 in approximately one half of the surface. Probably it would not be an overstatement to place at 50 the number of these radial braids actually departing from the center of the disk.

These radial bands are, however, simple for only a part of the radial length. At a point considerably within one half of the radius of the disk each tapers to a definite extremity. In other words, the smooth intervening areas bifurcate and the branches of each join with the branches at their side. Thus by the branching and inosculating of the intercalary areas the

braids of the median series are terminated and new series initiated, these arising within the branches mentioned. Several specimens show very clearly that the new series of braids begins at a given radial length and forms a distinct cycle. Still another bifurcation of the smooth radii occurs about half way between the first cycle and the margin of the disk, and this again occurs at the same radial distance for each radius. Each smooth intercalary area which starts from the center is represented by four branches at its distal termination. All radii, both structural and structureless, taper and become extinct within the margin of the disk, leaving a smooth border about the disk. The actual structure of the radial areas which we have spoken of as braids, though not apparent about the center, becomes clearer as these areas widen in the second cycle and pass to their final extinction in the third.

It is necessary to premise that the specimens showing this surface of the disk are preserved as sculpture casts, so that, while the actual substance of the body has been removed without replacement, we see the surface with the original relief of the exterior.

The broader parts of the radial braids, from near the commencement of the second cycle to their extinction, bear a regular succession of horizontal rows of pores. Beginning at the lateral margin of one of these poriferous areas or braids, two adjoining rows of pores will be found to converge slightly and terminate by such convergence. Such a pair of rows will have the position of its apex on or near the central line of the area and between the apexes of two similar pairs on the other half of the area. The rows of pores are separated by low ridges on the sculpture cast, but the ridges between rows of the same pair are distinctly less prominent than those between adjoining pairs. This structure is, as observed, most clearly retained over the second cycle of braids, where their diameter is greatest and both pores and poriferous plates are most pronounced; outward toward the periphery the horizontal extent of the pore rows is less, the pores themselves more restricted to the margins of the area and apparently of considerably larger size. The effect of this structure is to make the poriferous bands appear to

branch not far within their extinction, rather than the intervening unporous areas; an appearance well depicted in several of our figures but somewhat illusory as explained by the diagram (plate 5). We have then, evidently, in these porous radial bands, well defined ambulacral areas. The limits of their component plates are almost completely obsolete, but notwithstanding the general obscurity there are places where their margins are clearly discernible. The character of these ambulacral areas of the first cycle does not differ from that of later cycles, but their aspect is different: the close crowding of the alternating knots or short, horizontal ridges produces the braid-like appearance already described, and the pores are only obscurely shown, perhaps because of imperfect retention and perhaps from incomplete development; but when visible they are seen to lie in the grooves between the horizontal knots.

At the point of convergence of these radial bands near the center of the disk we have looked in vain for any evidence of structure. In three or four specimens this area is retained and in these it is simply a smooth, structureless spot where with the most obscure beginnings the ambulacral radii come into being. It is difficult to believe that the space did not possess some differential structure, but in that event it was of so delicate detail that it has been lost in the rather rude retention of these fossils. Nor is there any other single spot or area on this dorsal disk to which any special structure may be ascribed. Let us farther emphasize this significant fact; outside of the ambulacral areas there is no palpable evidence, either on the dorsal or ventral faces of the disk, of geometric plates, nor anywhere of a tubercled, scrobicular surface.

All the evidence, then, that can now be educed from this fossil leads to the following inference. The organism is probably an echinoid. In form it is a flattened, oval disk, not unlike Scutella in this respect. In an uncompressed condition the imperforate side may have been slightly concave; the other surface was distinctly convex. Its ambulacral region is restricted to one side, as in many clypeastroids and spatangoids. The imperforate side bears radiating and inosculating surface channels not unlike those of Scutella. The ambulacra are in

radial bands, which at the center of the disk are not less than 25 and are probably as many as 50 in number. These increase by the simple bifurcation of the long and narrow interambulacral spaces, at two distinct ontogenic periods, so that the outcome of this subdivision is three slightly interpenetrating cycles of ambulacral bands. No oral, genital or anal structures have been determined. The center of the surface is the point of convergence of all the ambulacral bands and is smooth or has not retained essential structural details. The existence of geometric plates on these ambulacra is shown in only a few places; most distinctly along the edges of the interambulacral spaces of the second cycle, where the lateral ends of the ambulacral plates make a visible notching of the margin, and again now and then the horizontal edges of the perforate plates are shown. In no part of the fossil is there evidence of plates on the imperforate surfaces.

The evidence of the presence of plates over the ambulacra is definite though imperfect, but their apparent total absence on the major parts of the surface of the body prompts the following suggestion. The matrix of the fossils, a highly laminated or "reedy" silico-felspathic sandstone, contains, in the Tannery gully at Naples, dictyosponges and considerable masses of comminuted floatwood, but no fossils with calcareous test of considerable thickness. Elsewhere this same Portage sandstone is not infrequently found to contain joints of crinoid columns preserved in the usual crystalline calcite. If these echinoid bodies, which we propose to term Paropsonema cryptophya, possessed a calcareous test in any degree corresponding to their considerable size, we should expect to find even in this arenaceous matrix some direct or at least more reliable indirect evidence of its presence. It may, therefore, be well to consider whether these fossils were not provided for the most part with a leathery or imperfectly calcified integument.

The foregoing description gives an account of the characters of this singular fossil so far as it seems possible to make them out. These are so unusual and so different from structures presented by the fossil and recent Echinodermata that it would be venturesome to make farther suggestions as to the probable affinities of the organism. The specimens and drawings

have been submitted to several accomplished morphologists, one of them, Dr Robert T. Jackson of Boston, specially familiar with the Echinoidea, and, while these gentlemen have kindly taken time for careful examination of the various structural features determinable, none have been willing to express a definite opinion as to the precise taxonomic position of the fossil. To one intimation from Dr Jackson however I shall take the liberty to refer, as it seems to some extent borne out by the material at hand. This is, in effect, that the ambulacral series 1 and 3 (*see* accompanying diagram, plate 5) may have been continuous in early stages of growth or in preexisting, more elementary types, and that series 2, therefore, may have been continuous from the center of the disk, thus making two series of small ambulacra, each bifurcating at its extremity in the region of the periphery. The suggestion, and it was intended to be no more than this, would imply that the discontinuity of the ambulacral series was due to the exigencies of growth, series 1 and 3 being crowded asunder by the lateral growth of series 2. Such a modification of structure would simplify the interpretation of the organism. Among the material illustrated is a young specimen not so distinctly preserved as some of the larger examples, but so far as it is possible to make out, these ambulacral rows do here appear to be continuous radii. Perhaps the fact should be stated in this way, that there is no very clear evidence of discontinuity or of cycles of these ambulacral radii in this young example, and so far as this specimen alone is concerned the suggestion of Dr Jackson is corroborated (*see* plate 9, fig. 1).

It may be well here to direct attention to a very noteworthy resemblance between this young specimen and the Discophyllum peltatum Hall, a fossil described from the "Hudson river" slates at Troy N. Y., which has recently been refigured by C. D. Walcott in his *Monograph of the fossil medusae*. I can not however look on the two as identical in all structural features.

There is excellent reason for expecting from the Portage rocks which have supplied these specimens of Paropsonema, other material which will retain additional details of structure sufficient to elucidate farther the anatomy and taxonomic position of this peculiar organism.

Plate 5

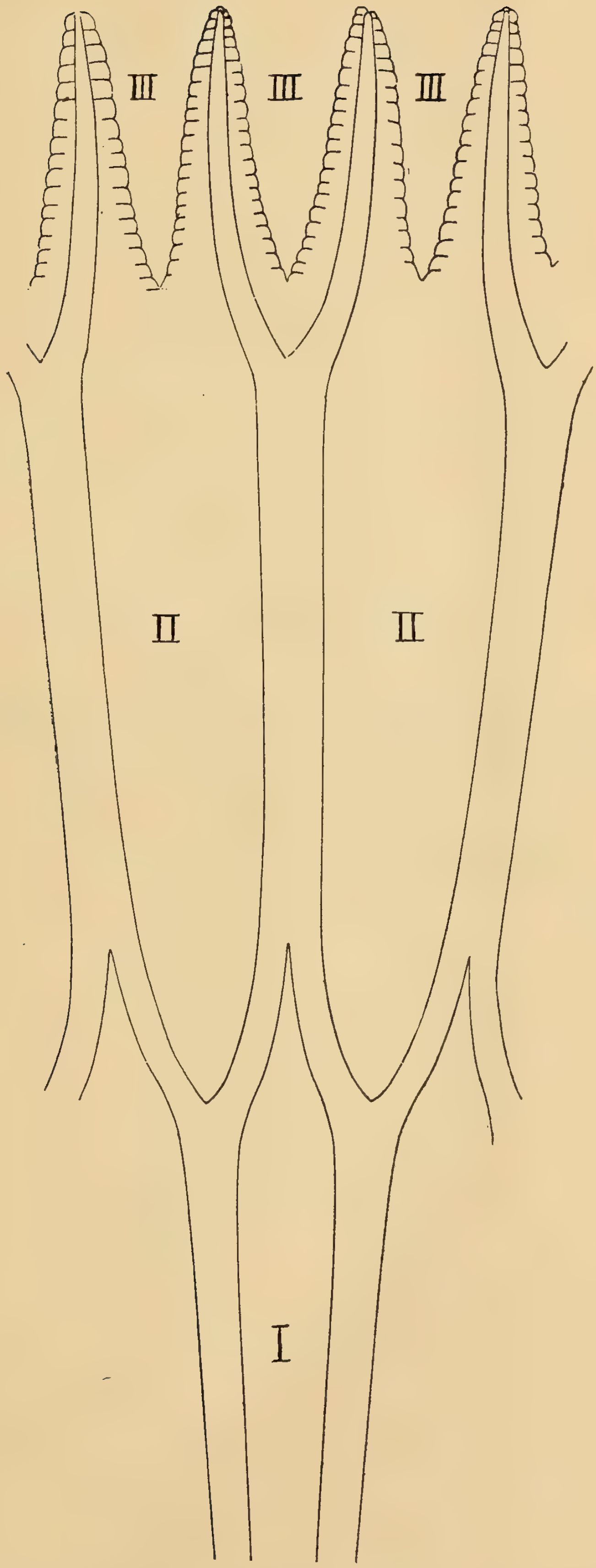


Diagram showing the 3 cycles of nonambulacral areas

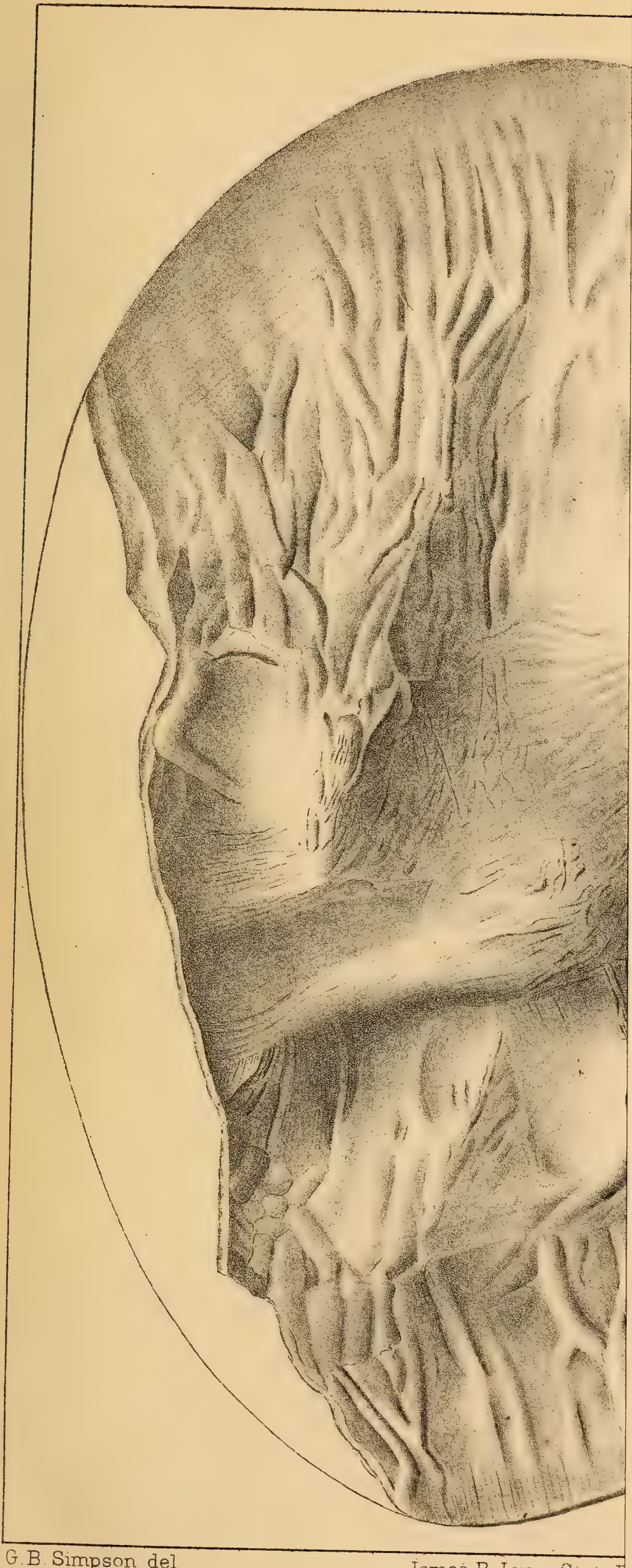
EXPLANATION OF PLATES

PLATE 6

Paropsonema cryptophya *Clarke*

The adambulacral surface of a nearly entire specimen with impressions of radial channels and integumental wrinkles.

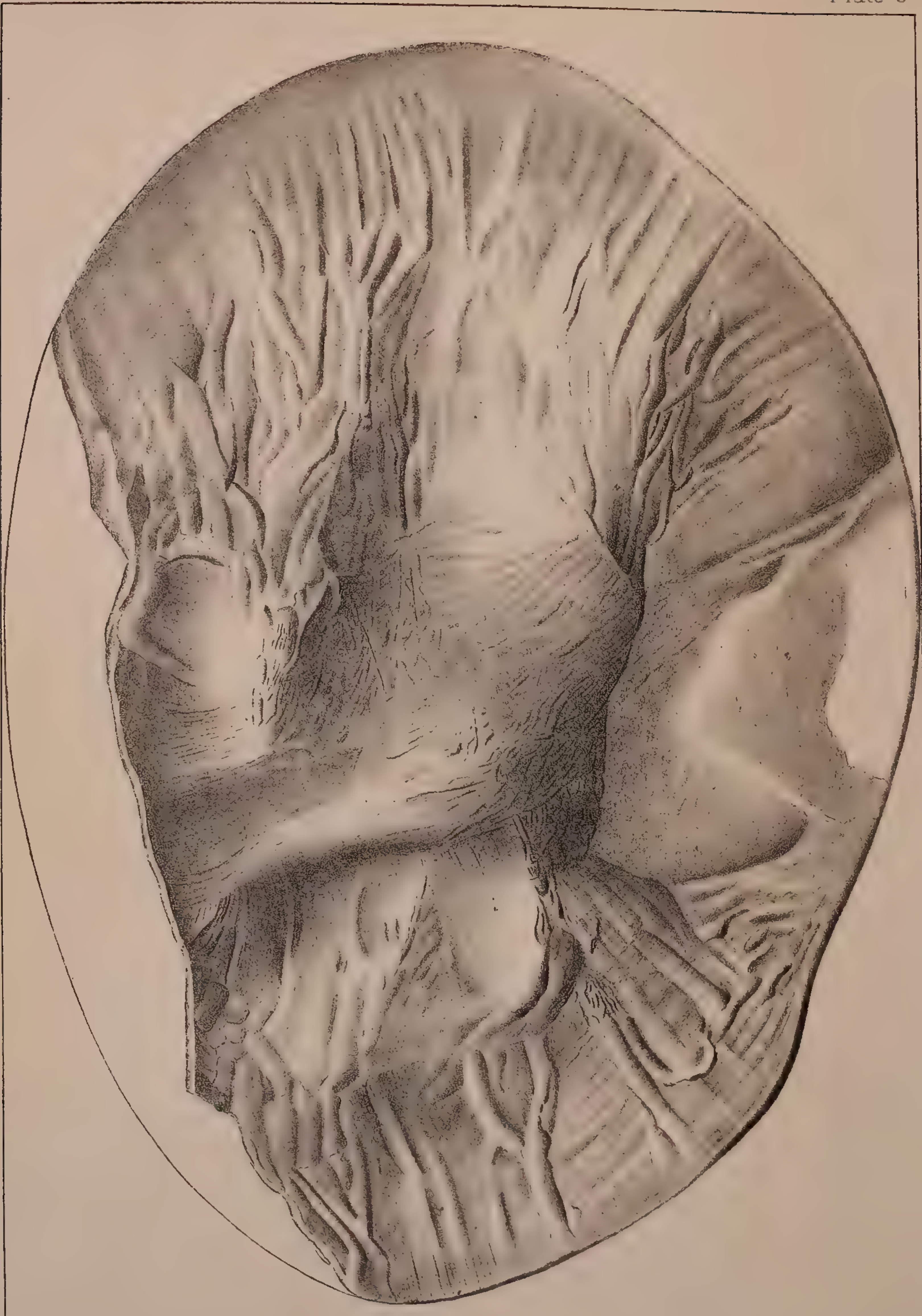
Portage sandstone. Naples N. Y.



G. B. Simpson del.

James B. Lyon, State P

PAROPSONEMA.

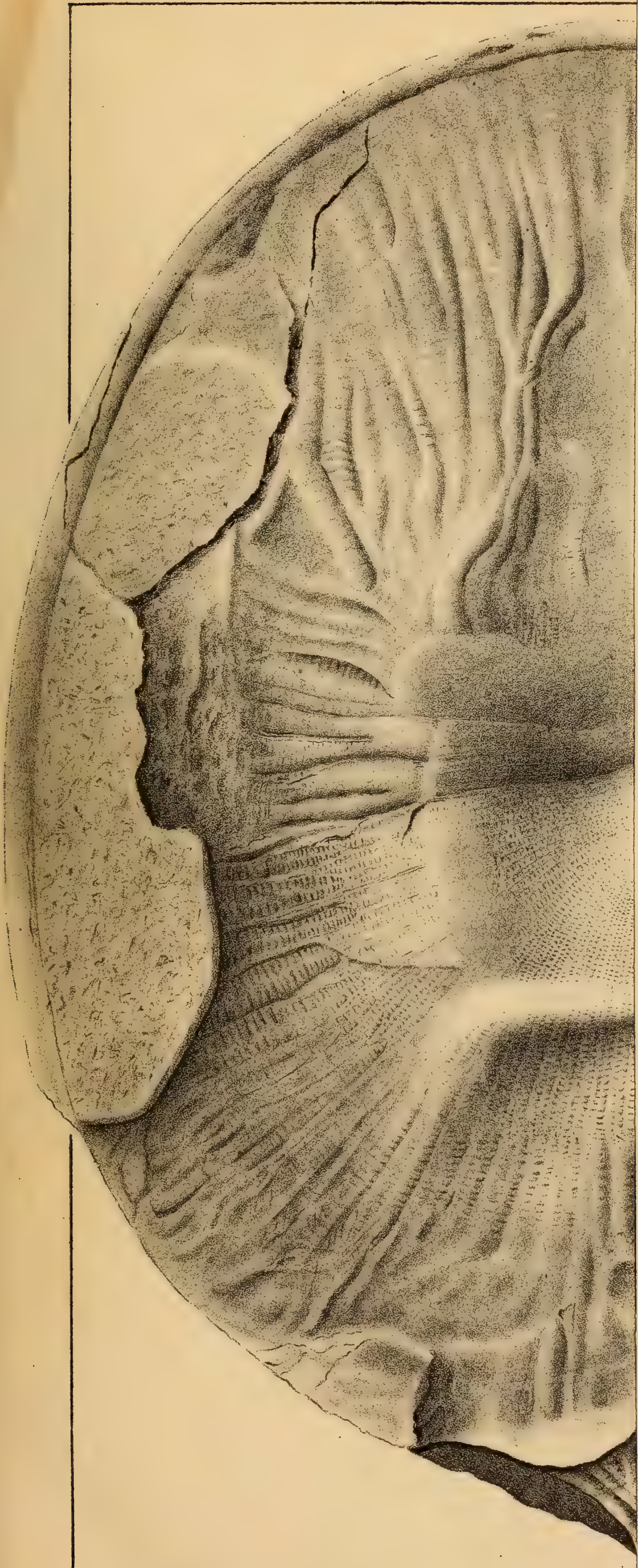


G. B Simpson del. James B. Lyon. State Printer. Philip Ast lith.

PLATE 7

Paropsonema cryptophya *Clarke*

The ambulacral surface with impressions of the radial channels belonging to the opposite surface of the test. This and the figure on plate 6 pertain to the same specimen.



G. B. Simpson del.　　　James B. Lyon.

PAROPSONEMA.

G E Simpson del. James B Lyon. State Printer. Philip Ast lith

PLATE 8

Paropsonema cryptophya ***Clarke***

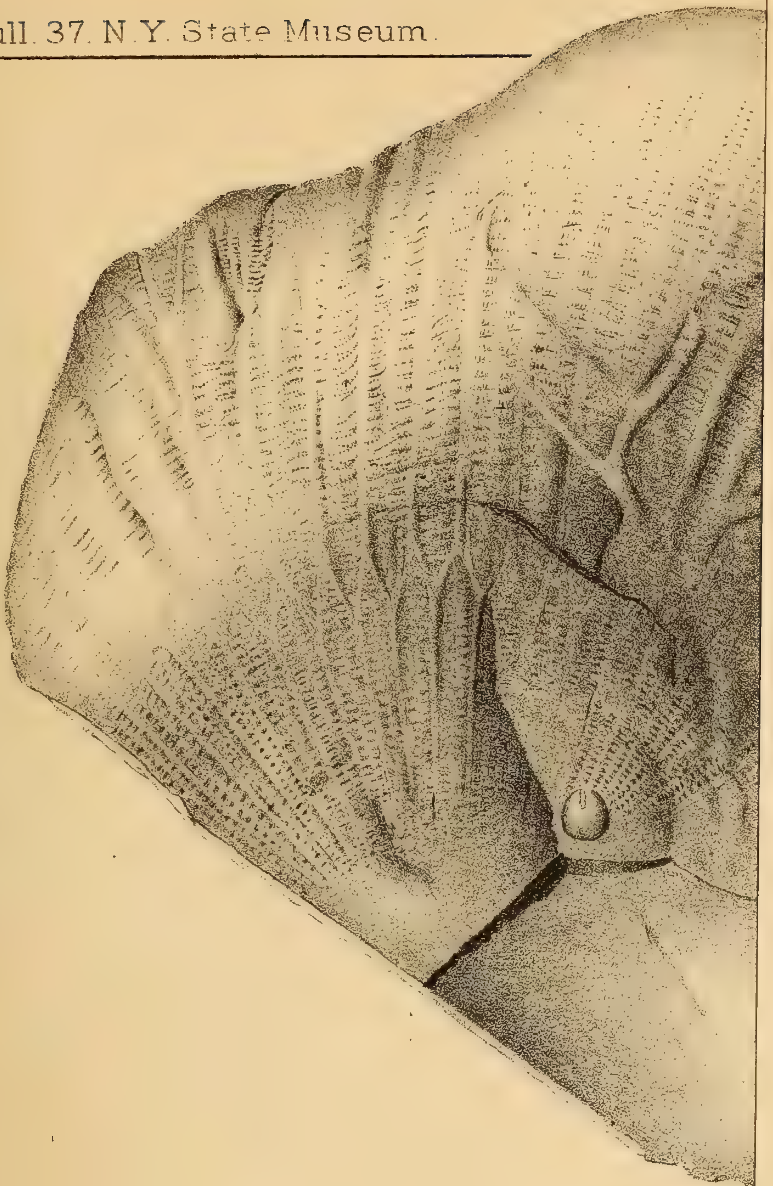
Fig.

1 The half of a specimen, showing the three cycles of ambulacral bands and the smooth peripheral surface.

2 An infolded and imperfect specimen which preserves some of the detail with clearness.

PAROPSO

1



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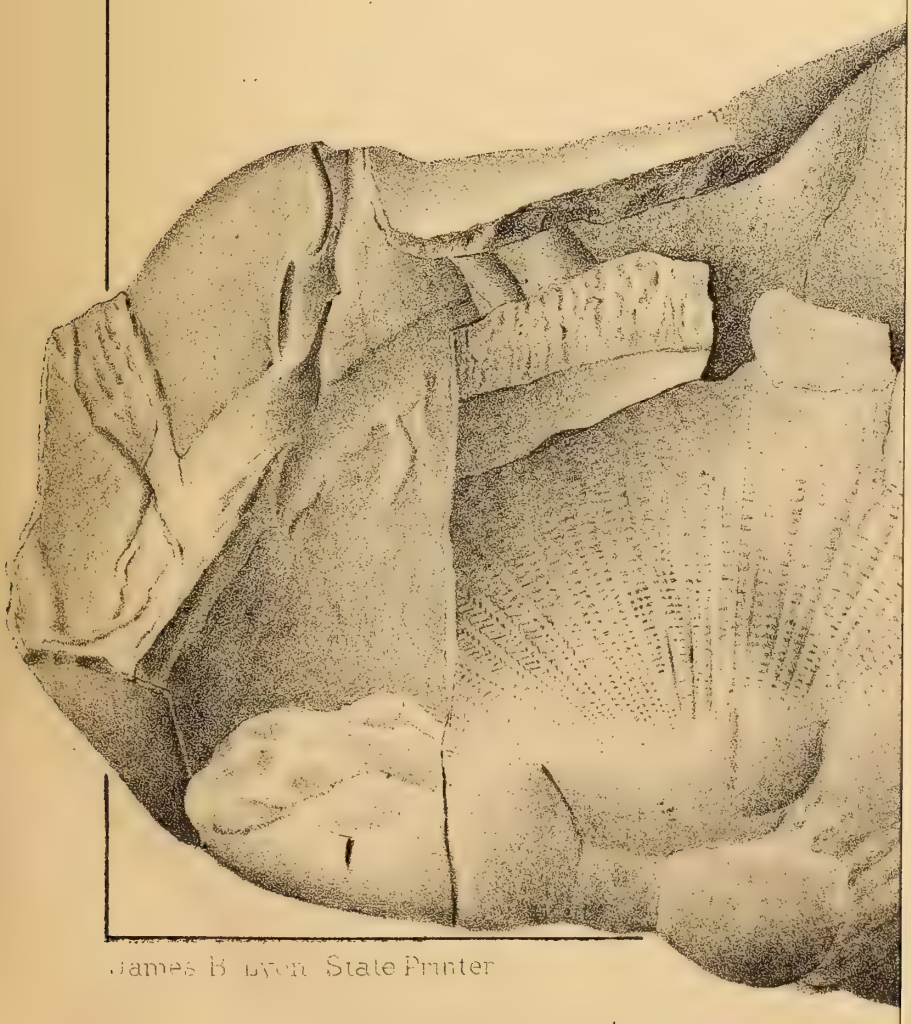

James B. Lyon State Printer

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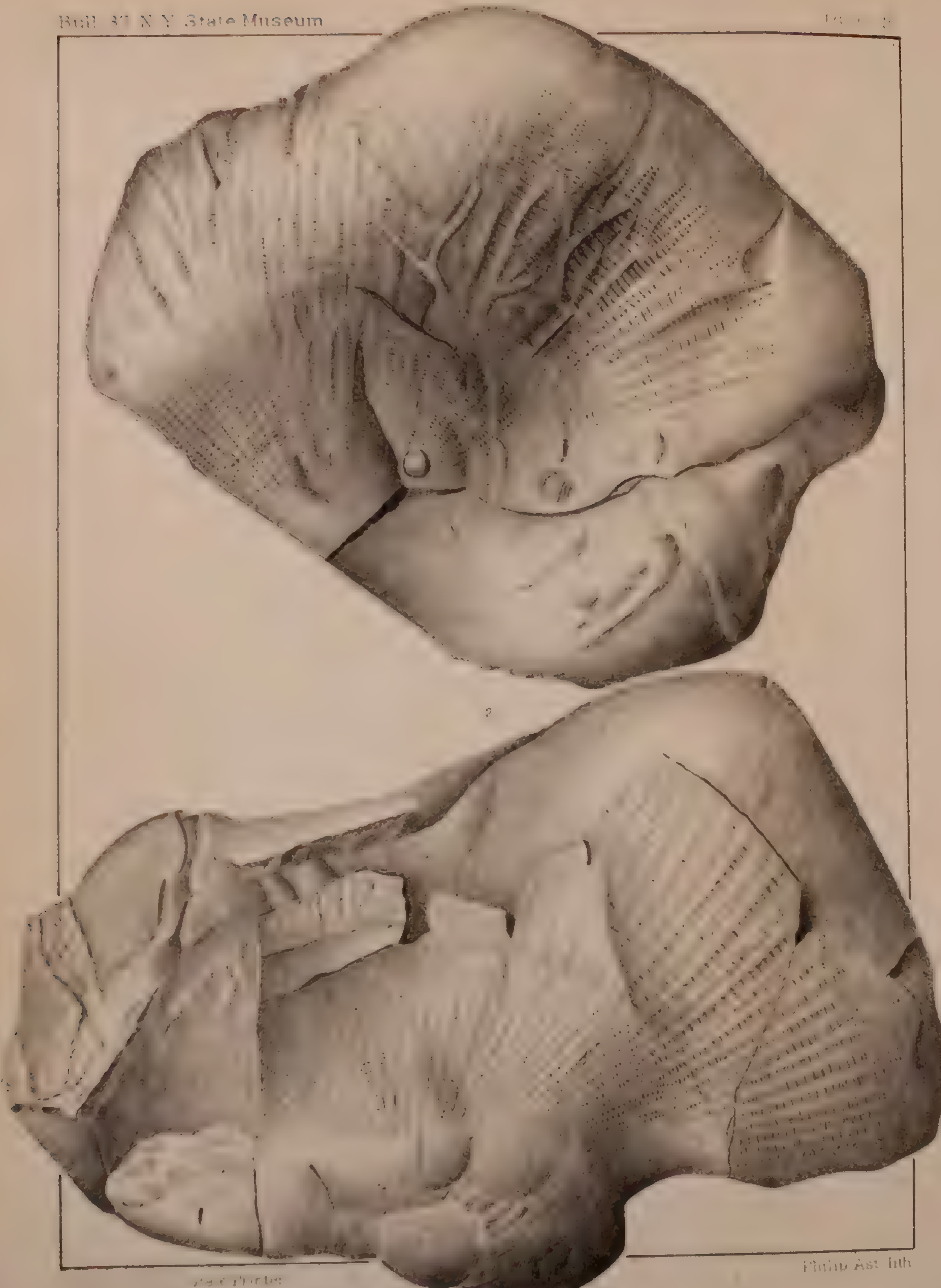


2

Philip Ast lith

PLATE 9

Paropsonema cryptophya *Clarke*

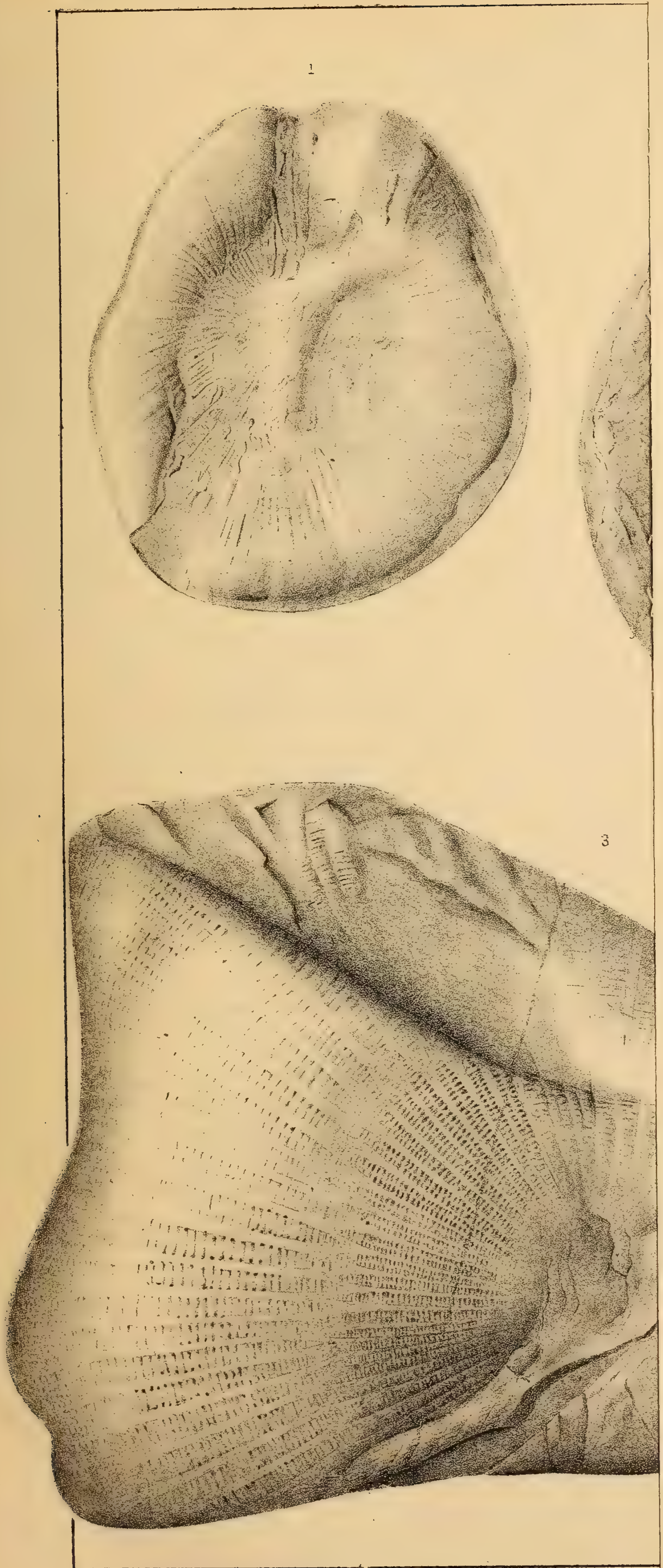
Fig.

1 A young specimen in which the detail is not very clear, but indicates no evidence of the second cycle of bands.

2 The adambulacral side of another young specimen.

3 The ambulacral side of an infolded and distorted example with the structure of the ambulacral and interambulacral areas quite clearly shown.

PAROPSO



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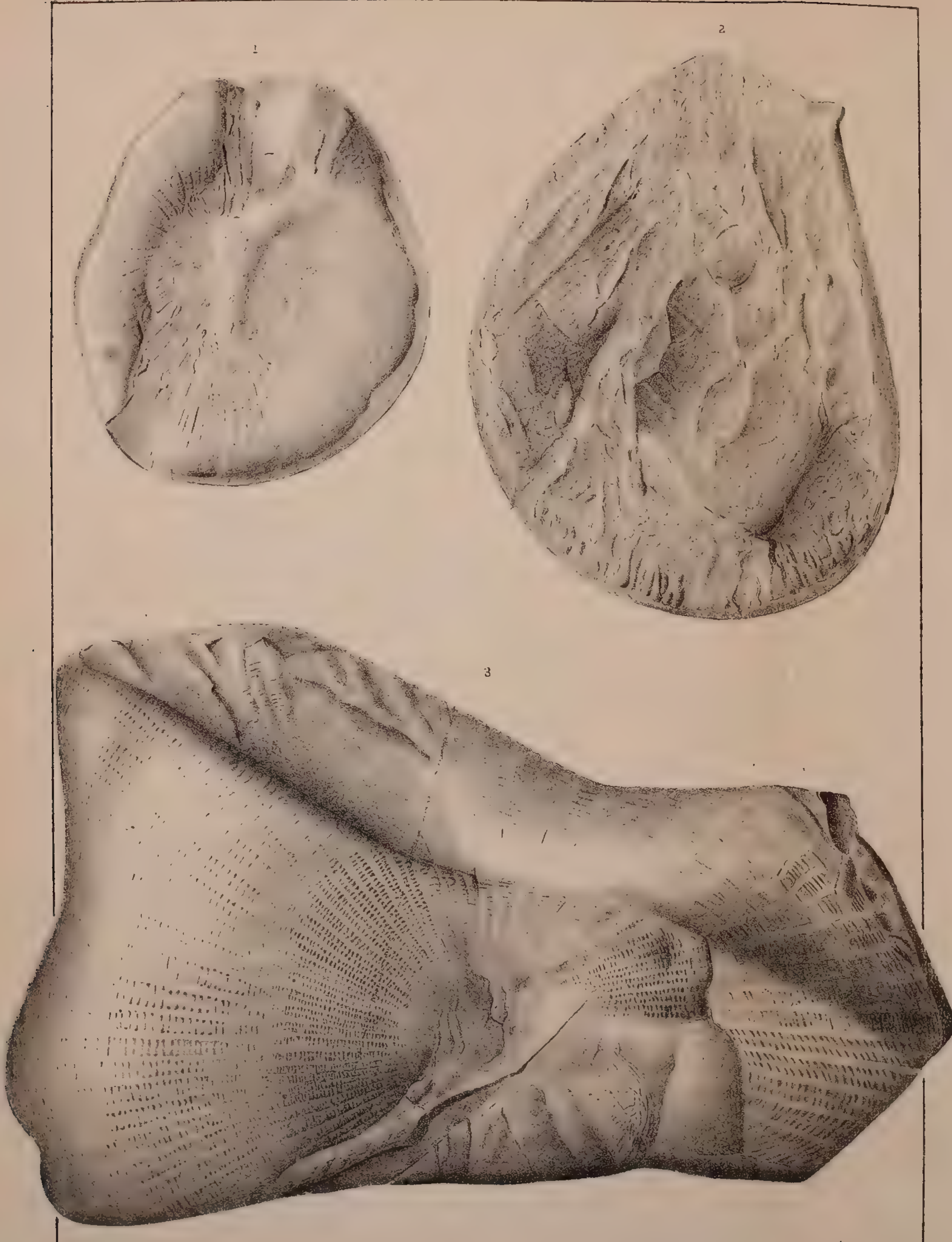

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James B Lyon State Printer

Philip Ast lith.

DICTYONINE HEXACTINELLID SPONGES FROM THE UPPER DEVONIC OF NEW YORK

BY JOHN M. CLARKE

(Plates 10-11)

A most striking characteristic of the shallow water fauna of the Chemung beds of the middle Upper Devonic is its great development of Hexactinellida, or silicious reticulate sponges. The evidence of the fruitfulness and multiplicity of these organisms at that time is of comparatively recent date. By the publication of Memoir no. 2, of the State museum (*The paleozoic hexactinellid sponges constituting the family Dictyospongidae*, 1899) more than 70 species of the fossils, assigned to 16 genera, have been made known from this formation. The demonstration of such an extensive development could have been possible only with the assistance of very large collections, and while these have shown that such fossils abound in a most unforeseen profusion, yet it is clear that they are more or less localized in their distribution. At present they appear to have multiplied most rapidly and varied most in the Chemung rocks of the central and southwestern parts of the state of New York, particularly in southern Ontario, Steuben, Allegany and Cattaraugus counties. In these regions various well defined plantations have been located, some of which have already yielded, and others doubtless would yield on exploitation, thousands of individuals. Eastward in the outcrops of this formation, these sponges become of rare occurrence, and outside of this state but very few have been found in rocks of this age. All of the forms hitherto described have been embraced within the somewhat conventional limits of the family Dictyospongidae, and have been shown to belong to the hexactinellid suborder, Lyssacina.

In the species of this suborder the skeleton is distinguished by the independence of the spicular elements. Whatever the modification which the fundamental hexactin may have undergone, however unlike in its various expressions, yet each spicule is inde-

pendent of all its neighbors in the skeletal complex, each leads an individual existence. In the suborder Dictyonina, however, the skeleton becomes continuous and, indeed, complicated by the fusion of the spicules. The arms or rays of one unite with the corresponding parts of those adjoining, and instead of having to deal with a structure whose elements retain the typical hexactine form, we find a skeleton divided into series of cubical meshes. While there is generally a close adherence to this type form, yet by the modification of the spicular elements there often results an irregularly meshed skeleton whose derivation from the hexactin is not always clear.

The silicious sponges of the Chemung fauna have in all cases yet brought under observation had their original silica replaced, first by iron pyrites, which in the porous, sandy matrix has changed to the peroxid of iron, and this salt for the most part deoxidized and thus removed by solution or carried away in the insoluble slate in suspension. There is not, thus, any way of eliciting the complete spicular structure of such bodies. We find their reticulate structure well exhibited on casts of exterior and interior in cases where the network was strong and the bundles of rod-like spicules well defined. In other cases we may observe rusty traces of the original network, which manifest themselves most clearly when the specimen is moistened. At the present most of the large mass of material representing these fossils, which has come under observation, has been obtained from surface exposures and loose blocks. Possibly fresh rock from a sufficient depth may eventually afford sponges from this fauna in which the pyrite of the skeleton will not have been decomposed. For our present interpretation of many details of structure observable in these fossils from the sandstone, we are largely dependent on correlations with the pyritized skeletons of dictyosponges found in the calcareous shales of the Keokuk beds, at Crawfordsville Ind.

The specimens which we here bring forward as representatives of ancient dictyonine sponges of Chemung age, present evidence of a skeleton whose meshes are small and irregularly polygonal.

In one of the two species described these meshes are somewhat larger in vertical diameter and many retain a rectangular form, but the branches freely inosculate and the quadrate form is not long maintained. An examination of the accompanying figures will show that these bodies present an aspect somewhat similar to that of a Dictyonema, which is however purely simulative. Found among dictyosponges, their skeleton is preserved in like manner to those.

Order HEXACTINELLIDA

Suborder Dictyonina

Family **Nepheliospongidae**, *fam. nov.*

Vase-shaped sponges, moderately thick-walled as indicated by the incurvature of the aperture. The tissue of inosculating spicules divides the surface into small, irregular polygons.

Genus NEPHELIOSPONGIA, *gen. nov.*

With the characters above specified. Surface smooth, free of ornamental protuberances or prostalia; in one species apparently corrugated horizontally. Apertural edge rounded and broad.

Type: *Nepheliospongia typica*, sp. nov.

Nepheliospongia typica, *sp. nov.*

Plate 10, fig. 1-3

This species takes on the form of a rather small, obconic cup, expanding with apparent regularity and evenly convex surface. The meshes of the surface are not all so polygonal as represented in the figure, but some show a more distinctly quadrate outline. Though the cups of two specimens have been somewhat compressed, one shows the aperture complete, and the fact that the sponge wall appears to have possessed a somewhat greater thickness than in the dictyosponges. The specimens of this species found have the following dimensions. One has a length from aperture to near the original base of 41 mm; its apertural width is 34 mm. The other is about 25 mm long, having been broken

near the base; its aperture is 33 mm in greatest diameter. This species is from the sandstone of the lower part of the Chemung beds, at Deyo basin in the town of Naples N. Y., where it is associated with many characteristic species of the Chemung marine fauna together with the following lyssacine sponges: Hydnoceras variabile H. and C., Hydriodictya cylix H. and C., Ceratodictya annulata (Conrad).

Nepheliospongia avocensis, *sp. nov.*

Plate 10, fig. 4; plate 11, fig. 1

This is a much larger sponge, of more funnel-shaped aspect, and with rather coarser but not different reticulation. Its surface presents a series of low, transverse corrugations which may, perhaps, arise from oblique compression but appear to be normal, as they occur in both of the examples observed. One of these examples, though slightly defective at each extremity, has a length of 105 mm and the same width at the apertural end; the other, which is more complete, has a length and apertural width of 140 mm. Both are from a high level in the Chemung strata, near Avoca, Steuben co. More precisely, their locality is the sponge plantation on the Cotton farm, about 1 mile north of the village, a colony located by D. D. Luther and the writer, which has produced a considerable number of interesting dictyosponges. Hydnoceras tuberosum Conrad and H. avoca H. and C. are there by hundreds, and in addition to these may be mentioned the species Aristodictya typica, A. nodifera and Hallodictya cottoniana, H. and C.

EXPLANATION OF PLATES

PLATE 10

Nepheliospongia typica *Clarke*

Fig.

1 Lateral view of an elongate cup

2 A smaller specimen

3 The aperture of the same, showing the incurvature and thickness of wall

Lowest beds of the Chemung formation. Deyo basin, Naples N. Y.

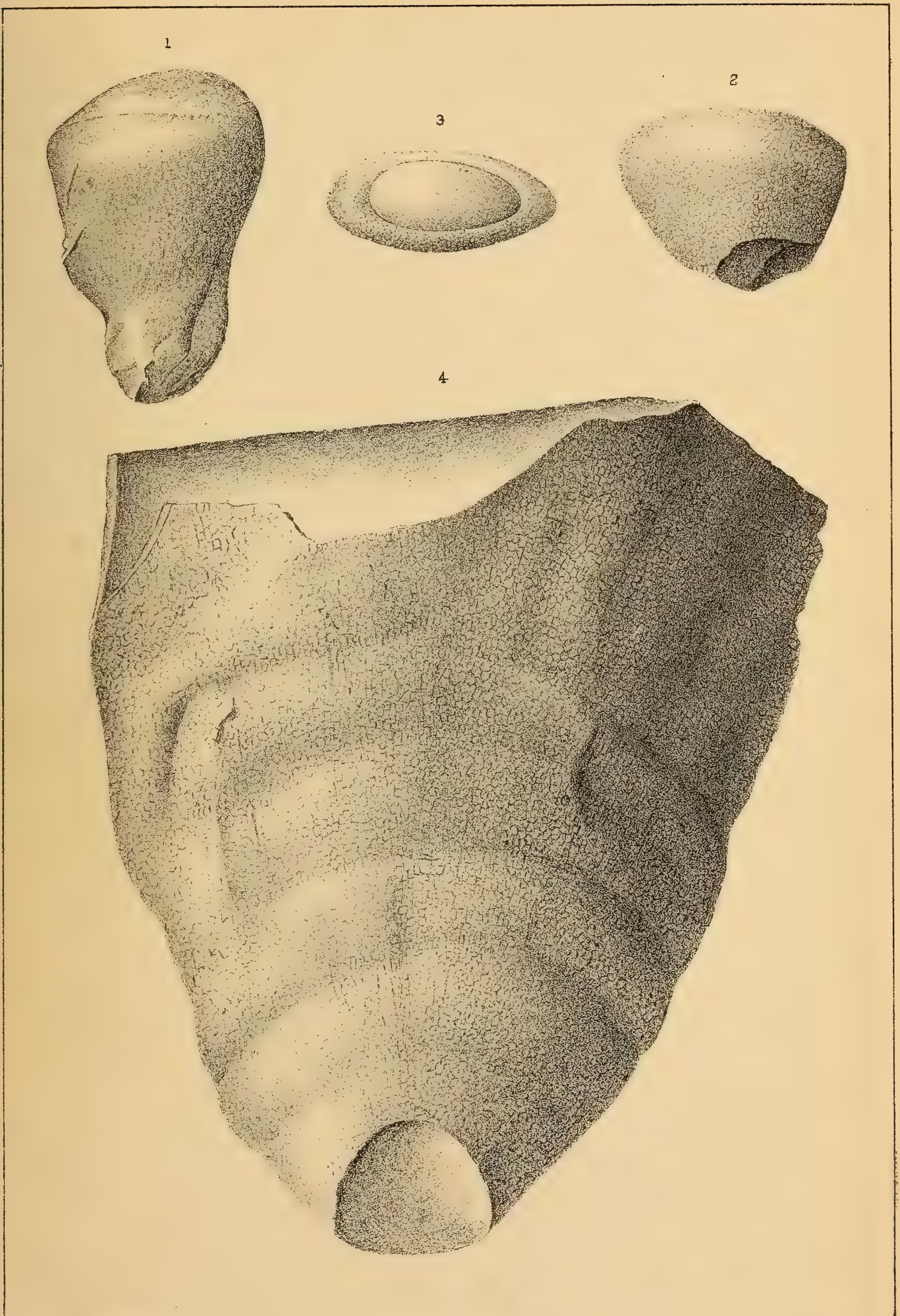
Nepheliospongia avocensis *Clarke*

(*See* plate 11)

Fig.

4 Specimen with somewhat undulated surface, showing the character of the reticulum

Chemung beds at Cotton hill, near Avoca N. Y.



G. E. Simpson del. James B. Lyon, State Printer Philip Ast lith.

PLATE 11

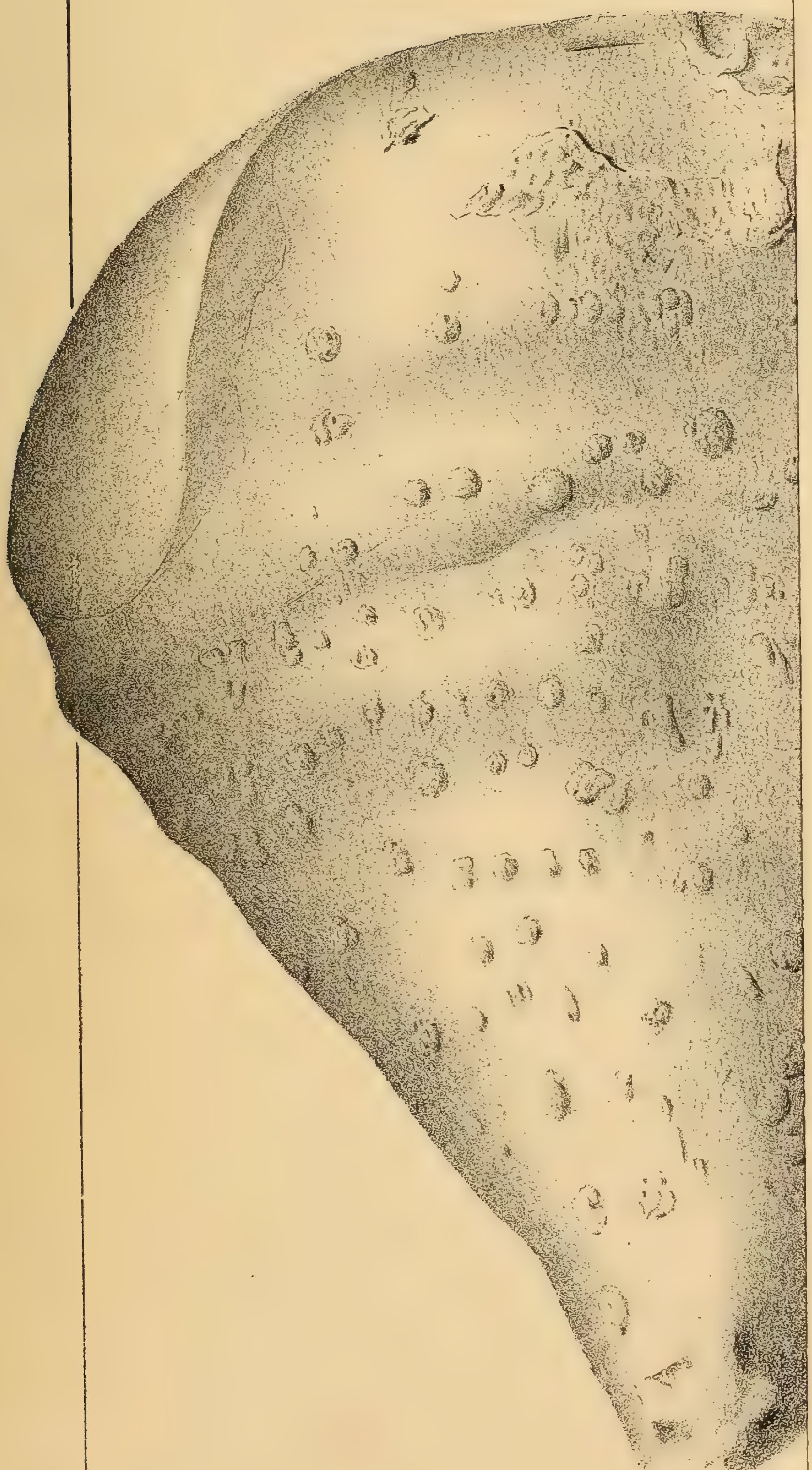
Nepheliospongia avocensis *Clarke*

(*See* plate 10)

Fig.

1 A large turbinate specimen with undulated or cinctured surface. Small patches of matrix are irregularly scattered over the wall.

Chemung beds at Cotten hill, near Avoca N. Y.



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THE WATER BISCUIT OF SQUAW ISLAND, CANANDAIGUA LAKE, N. Y.

BY JOHN M. CLARKE

(Plates 12-15)

Canandaigua lake is one of the well-known chain of Finger lakes in western New York which hang like pendants from below the south shore of Lake Ontario. This pretty sheet of water, about 14 miles long in its gently sinuous course, is a short section of an ancient waterway impounded by a dam of drift at its southern end. Near the lower or northern end of the lake, where its waters touch the village of Canandaigua, is its single island, a little spot of gravel and sand which the counter currents have piled up. Ever since Gen. Sullivan in 1779 carried firebrand and death among the Indians of this section, this bit of land has been known as Squaw island, and according to local tradition, here the women of the fighting braves took refuge from their burning villages. The adjoining sketch map shows the position of this island with reference to the shores of the lake. It will be seen that it lies west of the axis of the lake and opposite the *embouchure* of a little inlet. Its form is slightly elongated north and south, and from its northern end to the east side of the reedy cove, where the inlet comes in, a sand bar extends, along which at low water one can wade to the mainland. The inlet, which is known as Sucker brook, is a little stream which has grown smaller as the boys who played about it have grown to manhood. It heads in the northern part of the township of Canandaigua and in the upper reaches of its brief, meandering course of 8 or 10 miles it passes over a region of limestone and calcereous shales, cuts, kames and till piles where limestone boulders abound. In this way its waters have become well impregnated with lime. The north shores of Squaw island and the lake bottom about it and over its northward sand bar are covered with flat, whitish calcareous cakes of circular or oval shape, in

size ranging from a dime to a half dollar. To pick up one of these, well dried on the surface of the island and break it in half, seems enough to convince the reflective mind at once of their nature and mode of formation. It often contains as a central nucleus a beach pebble of shale or limestone, a twig, or a bit of charcoal from some youngsters' camp fire. About this a white or greenish travertine has been deposited in concentric layers which show themselves with distinctness. Often the interior of the cake is soft and powdery. Frequently the cake shows an imperfect fibrous structure. There is little doubt that this calcareous matter is constantly supplied by the influx of the lime-charged waters of Sucker brook. The little island and its bar lie directly in the course of this stream and receive the charge of carbonate of lime before these waters have diffused themselves over the wider surface and through the greater depths of the lake to the south. It is only on the north side of Squaw island that this water biscuit is found in abundance, and there almost every pebble is a biscuit. This apparently simple mode of concentric deposition in the formation of these bodies is of itself sufficiently interesting for record, and it would not be easy for the writer to cite a parallel. Here is actually a coarse, uncemented oolite forming under peculiar but very simple conditions.

This however is not the whole story. On picking one of the water biscuits from the lake bottom its surface is found to be smooth, slimy and often greenish; exposure on the shore bleaches it white. The calc-carbonate being dissolved in dilute acid and entirely removed, there remains a soft, spongy, organic residuum of precisely the volume of the original biscuit. From within will drop out the nucleus, rupturing the side of the soft mass. On examination, this organic matter proves to be a felted mass of filaments of fresh-water algae, which have been examined for me by Prof. C. H. Peck, the state botanist, and one of the species identified as probably Isatis fluviatilis. In the judgment of Prof. Peck there are several such species, and entangled among them are to be found diatoms, the whole so reproducing

Plate 12

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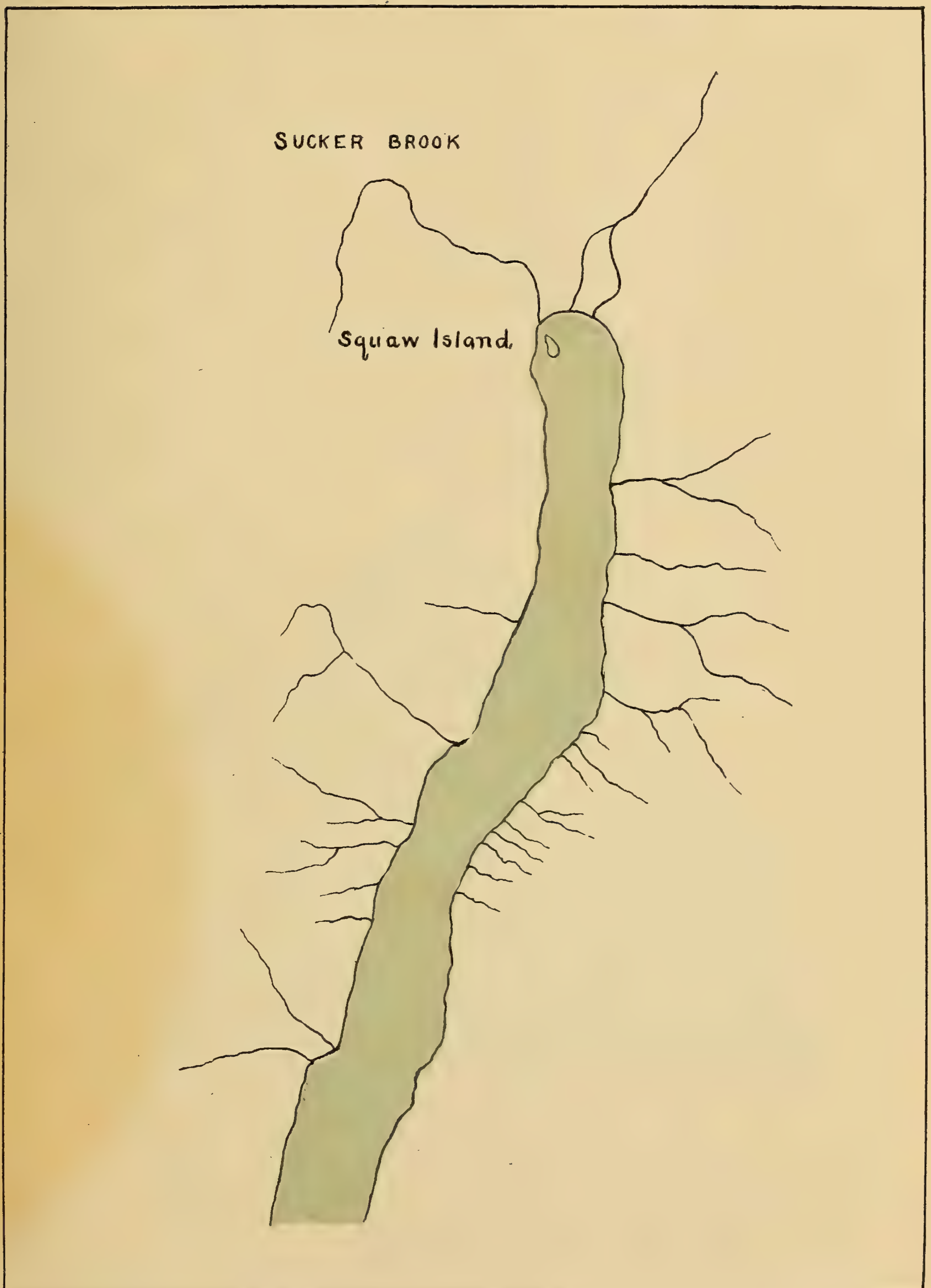

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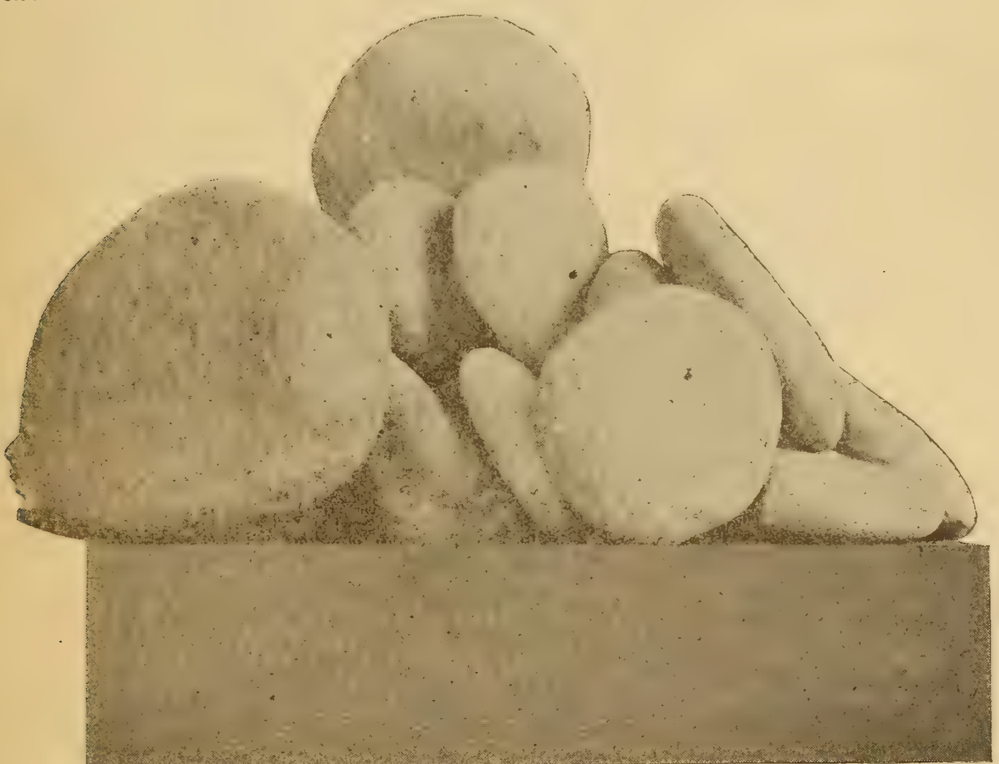
Map of the northern part of Canandaigua lake showing Squaw island and its relation to Sucker brook

the form of the biscuit as to make it clear that the calcareous deposit has been permeated with the organic matter.

It is quite clear that the process of formation of these peculiar bodies has been the following. The beach shale and débris have become incrusted by a growth of algae, and the latter, stealing away for their requirements the excess of free carbon dioxid in the water necessary to keep the carbonate of lime in solution, have thus caused a precipitation of the lime salts. The process has been continuous, as when a new precipitation formed a concentric continuous deposit of lime carbonate, the new surface became coated with the algae and in consequence fresh precipitation followed. The whole forms a most interesting instance of the influence of plant growth on the formation of lime deposits.



A group of Squaw island water biscuit.

It is appropriate to note in this connection that European authors have recorded the occurrence of similar spheric masses of filamentous algae in various fresh and brackish lakes. Some of these bodies from the lochs of the Hebrides have been described and illustrated by Barclay, who designates them as *algoid lake balls*.[1]

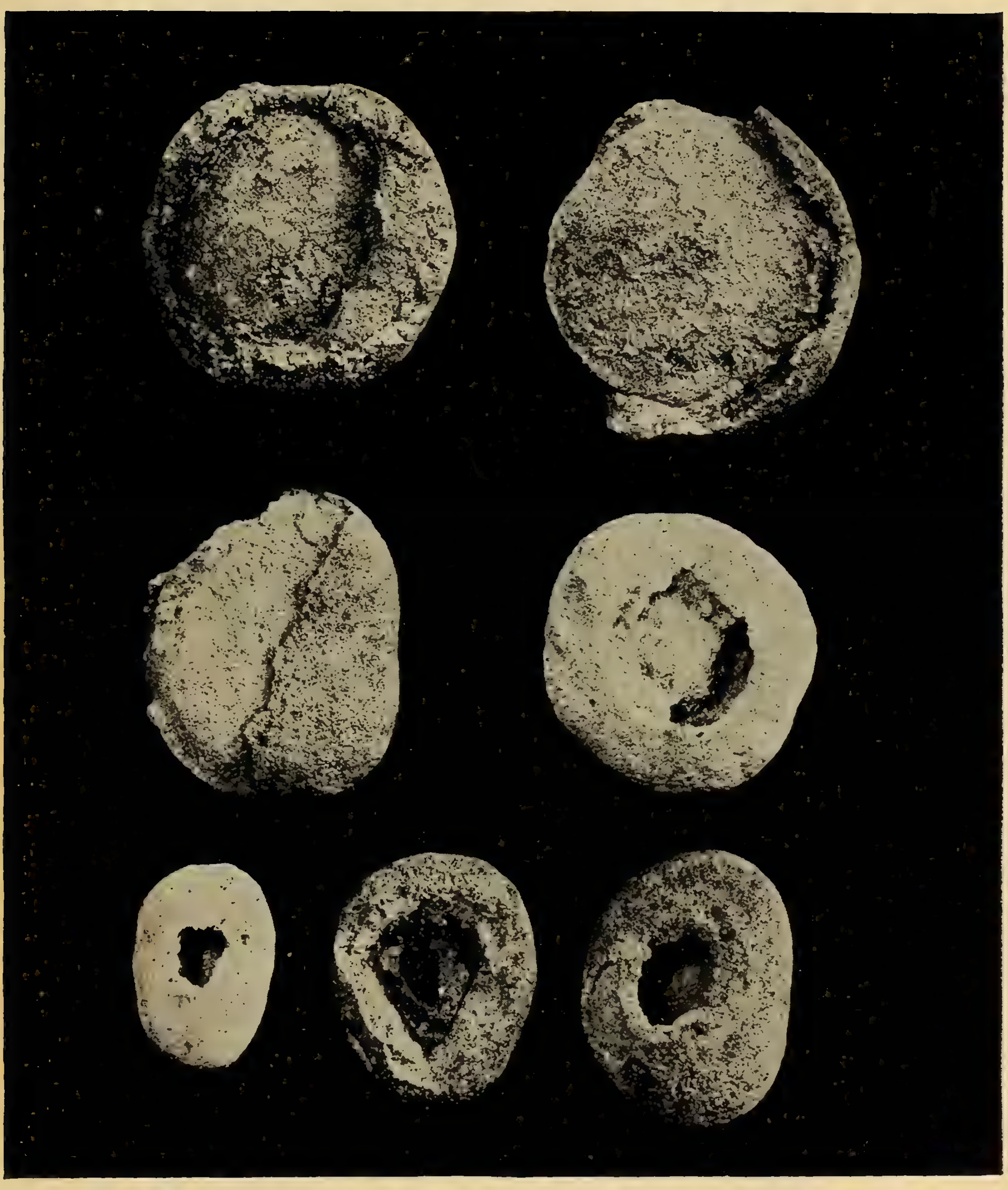
1 G. W. W. Barclay, "On some algoid lake balls found in South Uist." Proceedings Royal soc. Edinburgh. 1886. 13: 845, pl. 30.

These masses are described as composed of "innumerable alga filaments so intertwined and matted together as to form an outer covering of almost felt-like consistency which could not however be torn open without difficulty. This outer coating varied from about $\frac{1}{20}$ to $\frac{2}{20}$ of an inch in thickness, and the interior of the balls consisted so far as the naked eye could see only of mud. . . A microscopic examination of the balls shows that they are composed of a filamentous alga, Cladophora glomerata. . . The interior is seen to be filled with diatoms and the decomposing inner ends of the radiating filaments". Similar bodies, it is stated, come from Ellesmere in Shropshire and from the lakes of Sweden, Norway, northern Germany, Austria and upper Italy. These so called lake balls while organically similar to the water biscuit of Canandaigua lake, are entirely without calcareous deposit or inorganic nucleus. They would seem to be comparable to the condition of this water biscuit after the removal of the calcareous matter. While no explanation has been offered for the peculiar glomerated mode of growth of the alga, it may be that the noncalcareous lake balls have formed in waters without excessive content of lime carbonate. That the deposition of this lime carbonate in the formation of the water biscuit has gone on *pari passu* with the growth of the alga, as above suggested, seems quite clear.

Plate 13

Squaw island, Canandaigua lake, viewed from the mouth of Sucker brook and showing the sand spit and beach largely composed of water biscuit

Plate 14



A group of water biscuit showing the concentric calcareous layers and the nuclei

Plate 15

Water biscuit from which all calcareous matter has been dissolved leaving a mass of algous filaments

PRELIMINARY DESCRIPTIONS OF NEW GENERA OF PALEOZOIC RUGOSE CORALS

BY GEORGE B. SIMPSON

Prefatory note

The late Prof. James Hall had planned the preparation of a systematic treatise on the genera of the paleozoic corals, but during his life only the preliminary steps toward the execution of this important work were taken. The comprehensive purpose of the proposed treatise was actually the outcome and continuation of work done for volume 6 of the *Paleontology of New York* and for shorter papers in the annual reports, in the preparation of which the illustrations and analyses were essentially the work of George B. Simpson. Mr Simpson has continued these analyses for the execution, so far as seems practicable, of Prof. Hall's later plan, and in the course of his work has indicated several new types of generic structure, which are herewith made public in order to insure their claim to recognition, as some delay in the publication of the larger work is unavoidable. As these investigations were not reviewed by Prof. Hall, it is proper that the responsibility for their accuracy and stability should rest with Mr Simpson.

John M. Clarke
State paleontologist

Meniscophyllum, *gen. nov.*

Type: *Meniscophyllum minutum*, sp. nov.

Corallum minute, horn-shaped, regularly curved; calyx circular, deep; septal fovea conspicuous, situated on the side of the least curvature; septa apparently of the same size, but probably the smaller ones only rudimentary and, except in unusually well preserved specimens, obsolete. The extremities of the septa situated on the side of the greatest curvature become thickened and coalesce, forming in connection with a deposit of stereoplasma a thickened axis or pseudocolumella. In a longitudinal section this axis has the appearance of the columella of

Cyathaxonia. In a transverse section it is crescentiform; tabulae present; dissepiments not observed.

This genus most nearly resembles Menophyllum E. & H., but there is only one septal fovea, and the crescentiform thickening appears only in section and is formed in a different manner from that of Menophyllum.

Meniscophyllum minutum, *sp. nov.*

Corallum minute, horn-shaped, regularly curved; hight about 12 mm; diameter of calyx 7 mm; surface with wrinkles of growth and fine concentric striae; calyx oblique, walls thin; septa about 32 in number; the smaller ones rudimentary. The extremities of the septa of the cardinal and lateral aspects become thickened and coalesce, forming a pseudocolumella; septal fovea narrow; tabulae infrequent and very thin.

Formation and locality: Lower Carbonic, Missouri.

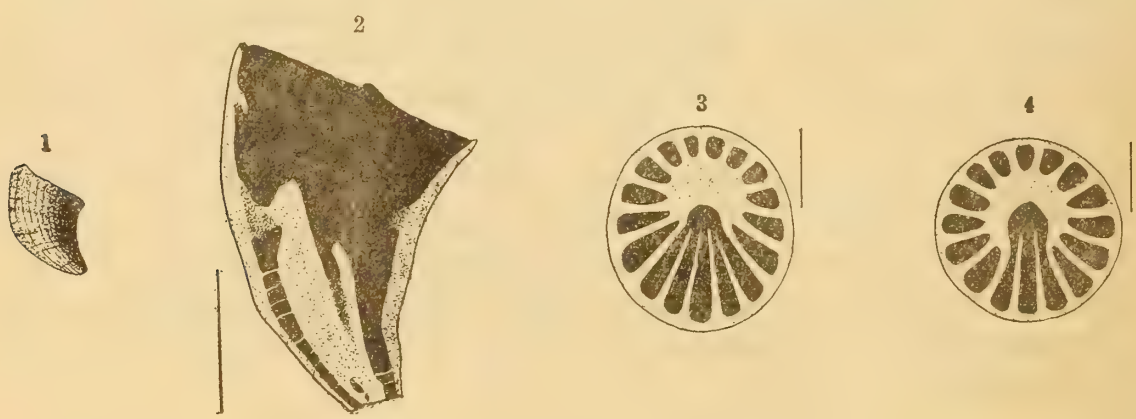


Fig. 1 Meniscophyllum minutum, nat. size
2 Longitudinal section, enlarged
3, 4 The crescentiform appearance of a transverse section of the pseudocolumella, enlarged

DITOECHOLASMA, *gen. nov.*

Type: *Petraia fanningana* Safford, Geology of Tennessee. 1869. p. 329. Helderbergian, Perry co. Tenn.

Corallum slender, attenuate, very gradually increasing in size; septa alternating in size, the larger ones continuing to or nearly to the center, becoming involved and forming a pseudocolumella, the smaller septa coalescing with the larger ones. The septa are arranged in pairs, each pair separated by a comparatively wide

interspace; the septa of a pair separated by only a narrow interspace, and having somewhat the appearance of a single septum with double walls; tabulae numerous, subcystose; dissepiments infrequent or obsolete.

The pseudocolumella has very much the appearance of that of Enterolasma, but the very different and peculiar arrangement of the septa easily distinguishes it from that species.

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Fig. 5 Ditoecholasma fanninganum (*Safford*). A transverse section, showing the peculiar arrangement of the septa, enlarged
6 A longitudinal section showing the pseudocolumella and tabulae, enlarged

LACCOPHYLLUM, *gen. nov.*

Type: *Laccophyllum acuminatum,* sp. nov. Niagaran group, Perry co. Tenn.

Corallum small, simple, cylindrico-conical, sometimes slightly curved; septa strong, alternating in size, the larger ones continuing to within a short distance of the center, where their extremities become broadened and fused, forming a distinct inner wall, leaving a cylindric central space, the smaller septa, at about one third the distance to the center, coalescing with the larger ones; tabulae present, those of the inner space strong, horizontal; of the peripheral space, much thinner and ascending from the outer to the inner wall, sometimes subcystose.

This genus in the manner of the formation of the inner wall resembles Duncanella truncata, but differs from that species in its frequent tabulae, and in the presence of tabulae in the central cylindric space.

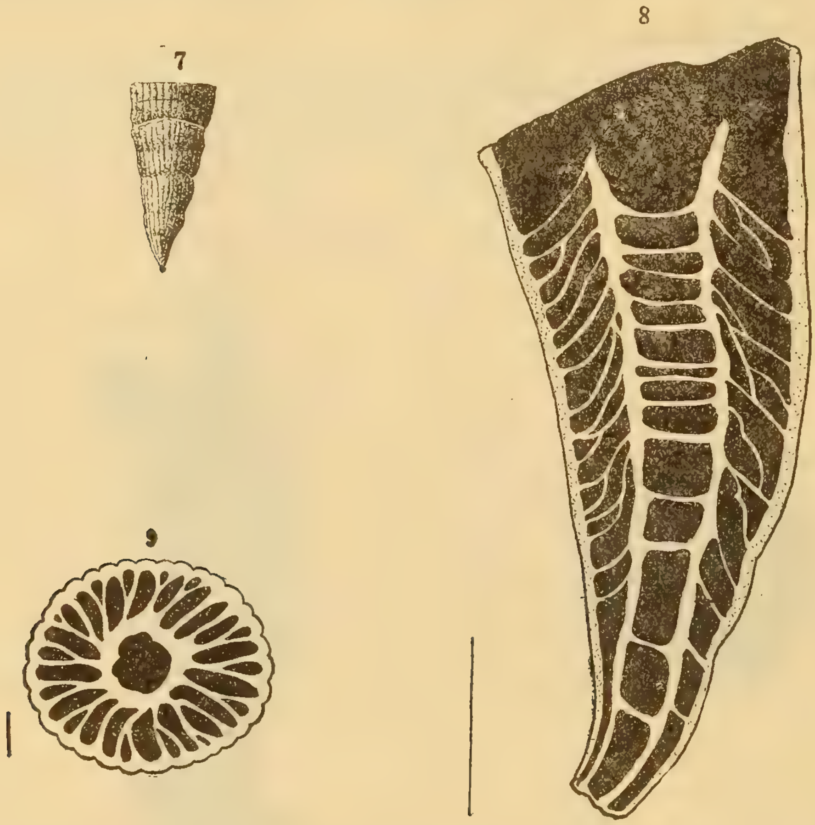

Fig. 7 Laccophyllum acuminatum. A lateral view, nat. size
8 A longitudinal section showing oblique tabulae, inner wall, and the horizontal tabulae of the central space, enlarged
9 Transverse section showing the septa and the inner wall, enlarged

Laccophyllum acuminatum, *sp. nov.*

Corallum small, cylindrico-conical, usually straight, but sometimes slightly curved; hight from 15 to 18 mm; diameter of the calyx from 6 to 9 mm; costae very prominent; septa alternating in size, the larger ones extending to within a short distance of the center, sometimes fasciculating, the extremities thickening, coalescing and forming an inner wall; tabulae frequent, curving abruptly upward, frequently presenting a cystose appearance. In the central space formed by the inner wall are frequent horizontal tabulae, somewhat stronger than the others, and apparently unconnected with them.

Formation and locality: Niagaran group, Perry co. Tenn.

HAPSIPHYLLUM, *gen. nov.*

Type: *Zaphrentis calcariformis* Hall. Fossil corals, Niagara and Upper Held. groups. 1882. p. 33, and 12th rep't of the state geologist of Indiana. pl. 21, fig. 10, 11. St Louis group, Washington co. Indiana.

Corallum small, simple, conical or horn-shaped; calyx circular, comparatively deep, with thin margins; biareal. The outer area is bounded by the external epitheca; the inner area by a subvertical wall of horseshoe shape, open on the side of the septal fovea. Two of the larger septa connect with this wall in such a manner as to be apparently a continuation of it, and form a very distinct pyriform septal fovea; septa alternating in size,

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Fig. 10 Hapsiphyllum calcariforme (*Hall*). A transverse section showing the coalescing septa, and the wall of the inner area, connecting with two of the septa.

the smaller ones continuing for a short distance into the cavity of the corallum, there coalescing with the larger ones, which continue to the inner wall, with which they coalesce, and in which they terminate. Tabulae and dissepiments are present.

The wall of the inner area, connecting with two of the septa and bounding a portion of the septal fovea, is similar to that of Agonophyllum, but that genus differs from this in several respects, principally in having carinations on the sides of the septa.

ENTEROLASMA, *gen. nov.*

Type: *Streptelasma strictum* Hall, 26th rep't N. Y. state museum nat. hist. 1874. Pal. N. Y. v. 6, pl. 1, fig. 1-10. Helderbergian, Clarksville, Albany co. N. Y.

Examples: *Streptelasma caliculum* Hall. Pal. N. Y. 1852. v. 2, p. 3, pl. 32, fig. 1*a-k*.

Streptelasma radicans Hall. 28th rep't N. Y. state mus. nat. hist. 1876. p. 106, pl. 5, fig. 1-4.

Petraia waynensis Safford. Geol. of Tennessee. 1869. p. 314.

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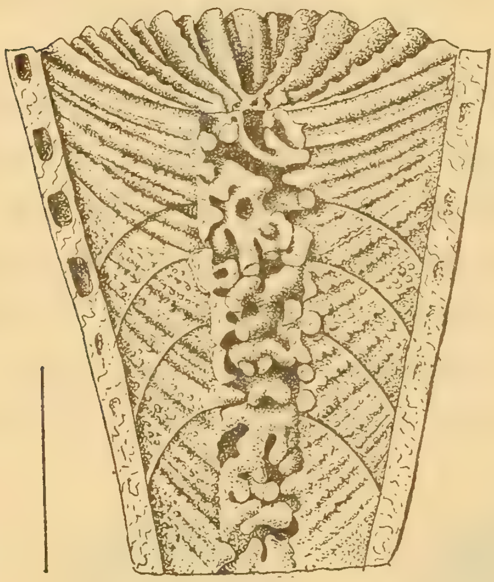

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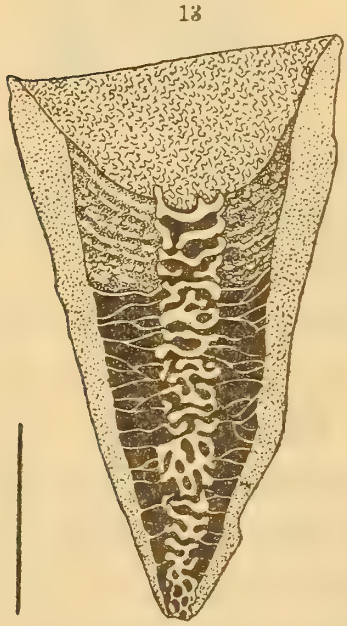

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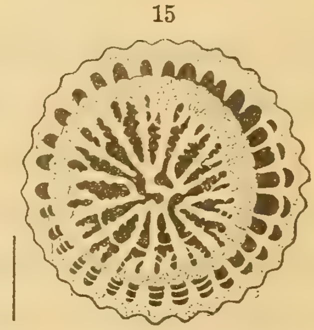

Fig. 11 Enterolasma strictum (*Hall*). A natural longitudinal section showing the pseudocolumella, the papillated carinae on the sides of the septa, and the ascending tabulae, enlarged

12 An enlargement from the center of the calyx, showing the involved processes from the inner margins of the septa

13 Enterolasma waynense (*Safford*). A longitudinal section showing the subcystose tabulae and pseudocolumella; the upper portion showing the papillate carinae of the septa, enlarged

14 A transverse section showing the thickened walls and the crenulations caused by the septal carinae, enlarged

15 A transverse section, showing an individual growing from the calyx of another, enlarged

Corallum moderately small, cylindrico-conical, usually straight, but sometimes slightly curved; calyx circular, moderately deep,

sides thin; septal fovea obscure, and in some species apparently obsolete; septa alternating in size, the larger ones continuing nearly to the center, having projections from their extremities which continue to the center, becoming much involved, forming a pseudocolumella of very peculiar appearance, somewhat resembling the convolutions of the intestines; sides of the septa with numerous papillate elevations or carinae, which in a transverse section give to the septa a crenulate or echinate appearance; tabulae and dissepiments present. The characteristic feature of this genus is the peculiar appearance of the pseudocolumella.

STEREOLASMA, *gen. nov.*

Strombodes? rectus Hall. Geol. rep't 4th district N. Y. 1843. p. 209, fig. 5.

Type: *Streptelasma rectum* (in part) Hall. Illus. Devonian fossils. 1876. pl. 19. Hamilton shales, western New York.

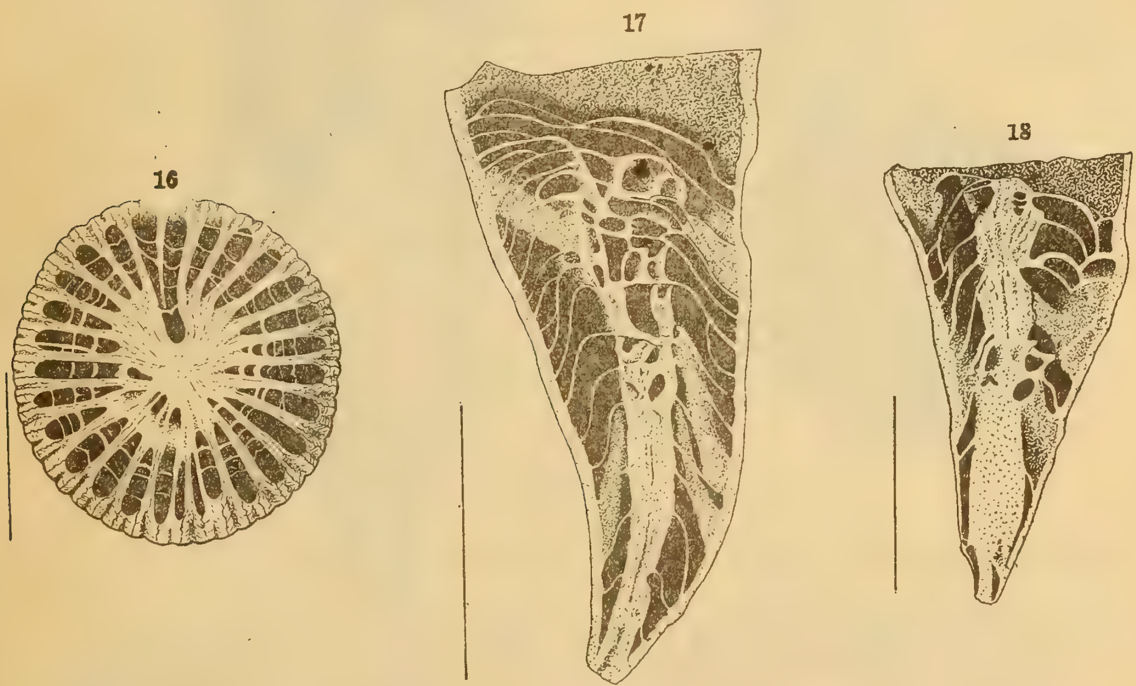

Fig. 16 Stereolasma rectum (*Hall*). A transverse section showing septa, dissepiments, and pseudocolumella
17 A longitudinal section showing tabulae and pseudocolumella
18 S. ungula (*Hall*). A longitudinal section

Example: *Streptelasma ungula* Hall. Illus. Devonian fossils. 1876. pl. 19. Hamilton shales, western New York.

Corallum varying in size, straight or curved, simple; calyx circular; septal fovea conspicuous; septa alternating in size, the larger

ones continuing to the center, straight or very slightly twisted; between the septa at the center of the corallum a deposit of stereoplasma, which has the appearance of a columella; tabulae and dissepiments frequent.

The pseudocolumella distinguishes this genus from Zaphrentis.

LOPHOLASMA, *gen. nov.*

Type: *Streptelasma rectum* (in part) Hall. Illus. Devonian fossils. 1876. pl. 19. Hamilton shales, western New York.

Corallum conical, straight, sometimes slightly curved at the apex, subrigid in appearance; surface with frequent annulations, and numerous concentric striae; costae distinct, flat or slightly rounded, the surface resembling that of Heliophyllum; septal fovea well defined; septa alternating in size, the larger ones

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Fig. 19 Lopholasma carinatum (*nom. propos.*) A transverse section showing the pseudocolumella, the septa, dissepiments, and the spur-like processes from the septa

20 Longitudinal section showing the pseudocolumella, septal carinae and the delicate tabulae

continuing to the center, where there is a deposit of stereoplasma forming a pseudocolumella, which does not extend beyond the bottom of the calyx. On the sides of the septa are strong, essentially horizontal carinae, extending from the exterior wall to the

extremity of the carina. In a transverse section, curved, spur-like processes are seen proceeding from the sides of the septa. The nature of these processes has not been satisfactorily determined. Tabulae are frequent, delicate; dissepiments frequent.

The type species of this genus closely resembles Stereolasma rectum, and from external characters alone they could not be separated, but by slightly grinding down the exterior, the difference can be at once seen.

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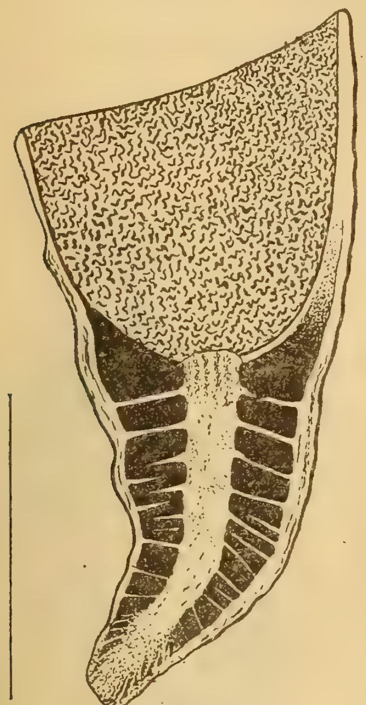

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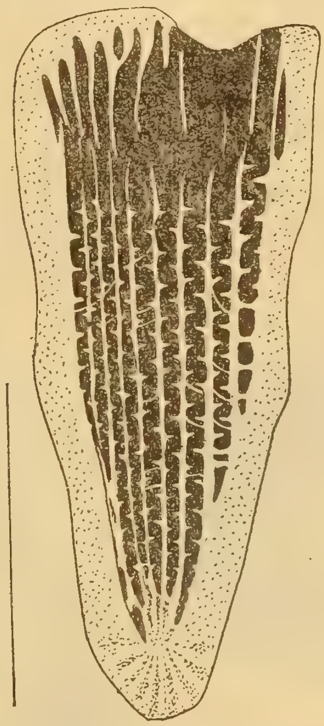

Fig. 21 Longitudinal section of the same showing depth of the calyx, pseudocolumella and septal carinae

22 Longitudinal section near the margin, showing the edges of the septa and the width of the carinae

Kionelasma, *gen. nov.*

Type: *Streptelasma mammiferum* Hall. Fossil corals of the Niagara and Upper Held. groups. 1882. p. 21, and 35th rep't N. Y. state mus. nat. hist. 1884. p. 425. Onondaga limestone, Falls of the Ohio.

Examples: *Cyathaxonia gainesi* Davis. Kentucky fossil corals. 1885. pl. 104, fig. 1-7.

Streptelasma spongaxis Rominger. Geol. sur. Michigan. 1876. pt 2, pl. 39.

Corallum variable in size, cylindrico-conical or horn-shaped; calyx circular or elliptic; septa alternating in size, the larger

ones continuing to or nearly to the center, where they become thickened and some of them much involved or twisted, forming a central spongy axis or pseudocolumella, which becomes solidified and projects prominently from the bottom of the calyx; tabulae and dissepiments present, comparatively infrequent.

This genus resembles Cyathaxonia, Lophophyllum, Axophyllum and others in having a strong projection from the bottom of the calyx, but internally it differs from all of them.

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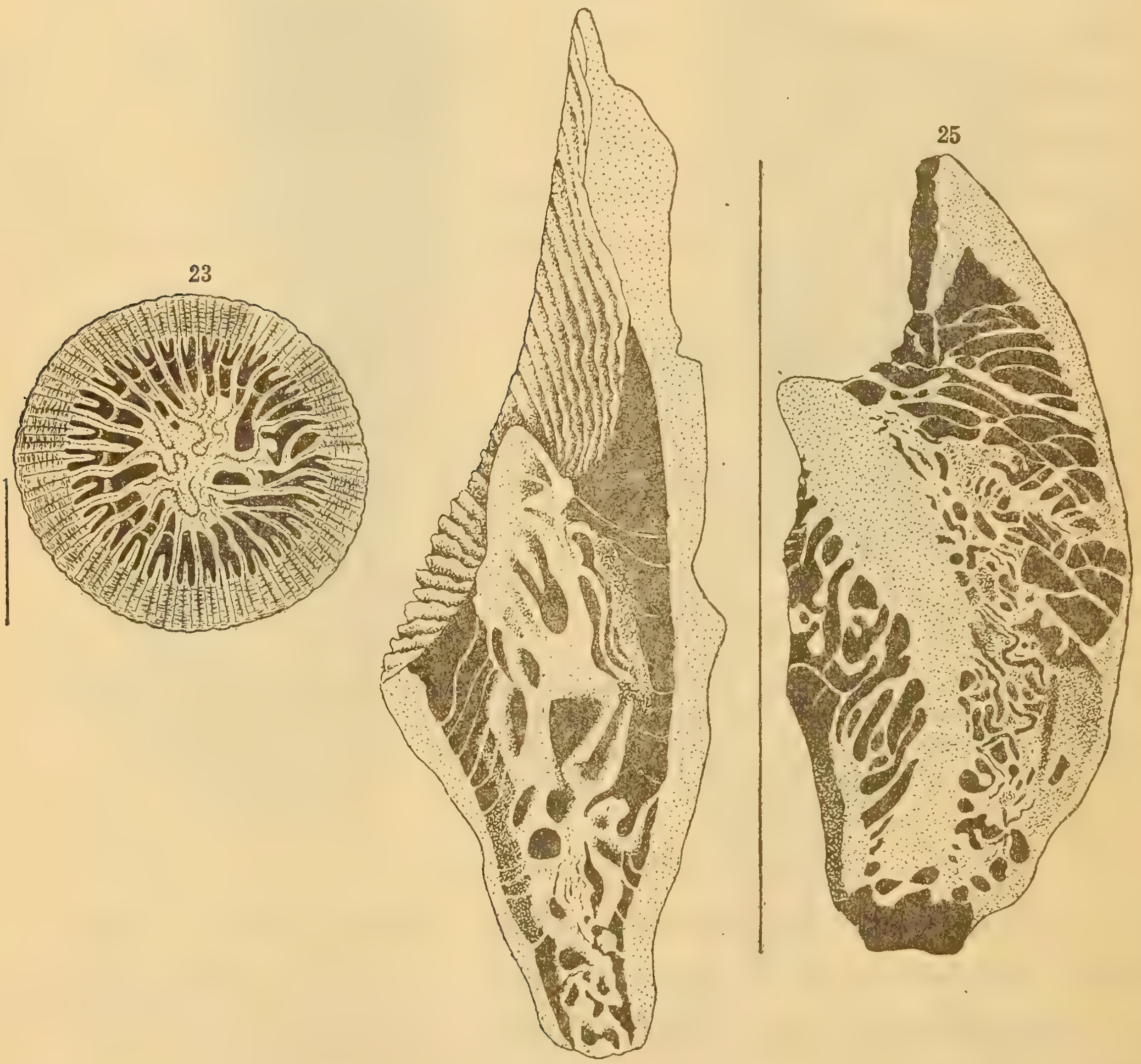

Fig. 23 Kionelasma mammiferum (*Hall*). A transverse section showing the septa and the pseudocolumella
24 A longitudinal section showing pseudocolumella and tabulae
25 Kionelasma herzeri (*Hall*). A longitudinal section showing the pseudocolumella and subcystose tabulae

Nicholson and Etheridge, in their *Monograph of the Silurian fossils of the Girvan district, Ayrshire*, pl. 5, fig. 2, illustrate the genus Lindströmia, the enlarged sections of which show a close resemblance to the structure of this genus. But the au-

thors say the pseudocolumella is formed by "the amalgamation of the inner ends of a larger or smaller number of septa, without any twisting of the septa, and being accompanied by a more or less copious secondary deposition of sclerenchyma."

In Kionelasma the twisting of the septa is one of the most pronounced characteristics.

TRIPLOPHYLLUM, *gen. nov.*

Type: *Zaphrentis terebrata* Hall. 12th rep't, geol. Indiana. 1883. p. 316, pl. 23, fig. 5. Onondaga limestone, Falls of the Ohio.

Example: *Zaphrentis centralis* Edwards and Haime. Monographie des polypiers fossiles des terrains palaeozoiques. p. 328, pl. 3, fig. 6.

This genus has the same general appearance and mode of growth as Zaphrentis, but in addition to the septal fovea there are two lateral foveae. The microscopic character is also different. In Zaphrentis the calcareous fibers of the septa are arranged obliquely outward from the median plate: in this genus they are arranged obliquely inward or toward the center of the corallum.

26 27

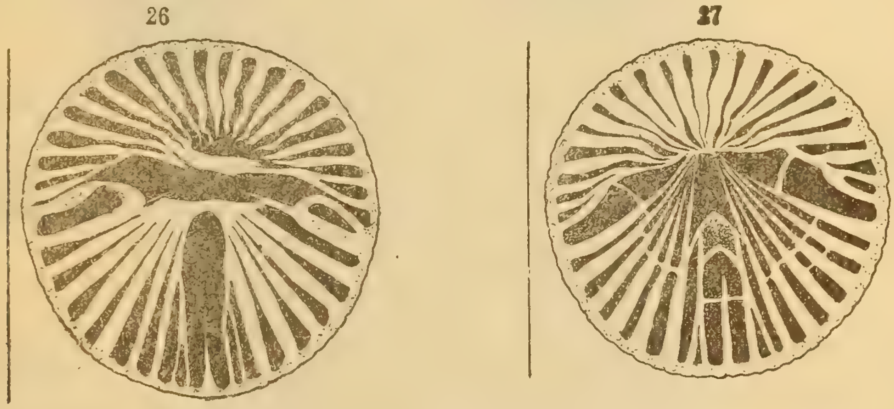

Fig. 26-27 Triplophyllum dalii (*E. and H.*). Transverse sections of two specimens showing the three septal foveae and the arrangement of the septa

CHARACTOPHYLLUM, *gen. nov.*

Type: *Camptophyllum nanum* Hall and Whitfield. 23d ann. rep't N. Y. state mus. nat. hist. 1873. p. 232. Lower Carbonic Rockford Ind.

This genus has essentially the same structure as Camptophyllum, with the exception that the sides of the septa are carinated, the carinations forming serrations or denticulations on the margins of the septa.

It differs from that genus in the same manner that Heliophyllum differs from Cyathophyllum.

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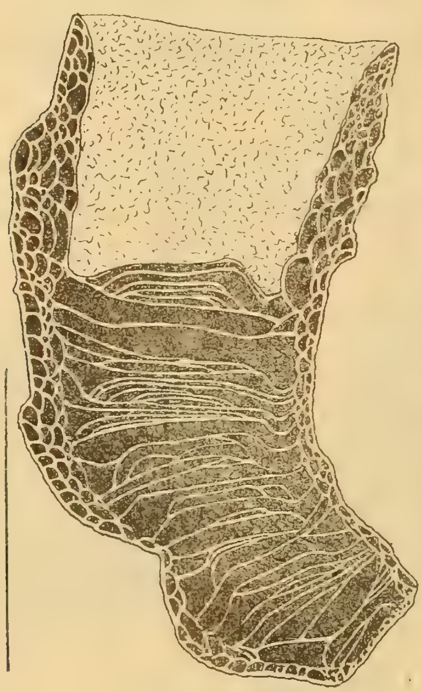

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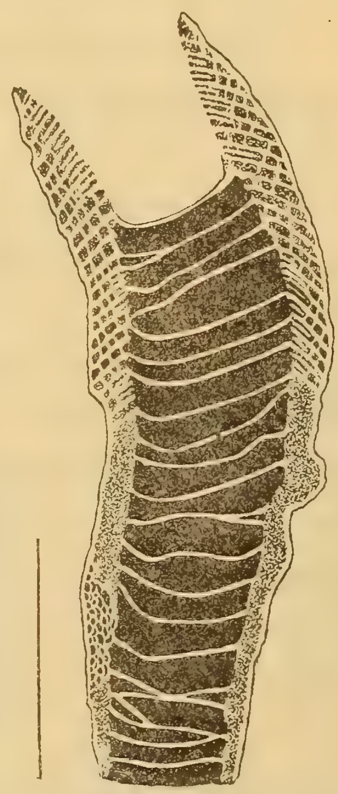

Fig. 28 **Charactophyllum nanum** ***H. and W.*** **Longitudinal section**

29 **Charactophyllum radiculum** ***Rominger.*** **Longitudinal section showing oblique carinae, cysts, and strong tabulae**

Odontophyllum, *gen. nov.*

Type: *Aulacophyllum convergens* Hall. Fossil corals of the Niagara and Upper Held. groups. 1882. p. 22, and 12th rep't Indiana geologist. p. 281, pl. 17, fig. 1, 2. Onondaga limestone, Falls of the Ohio.

Forms having the same characters as Aulacophyllum, but with the sides of the septa carinate and their margins denticulate as in Heliophyllum.

Scenophyllum, *gen. nov.*

Type: *Zaphrentis conigera* Rominger. Geol. sur. of Michigan. pt 2, p. 149, pl. 40. Onondaga limestone.

This form would be excluded from Zaphrentis on account of its conical tabulae and spirally twisting septa. It is very similar to Clisiophyllum, but is without the peripheral zone of cysts, characteristic of that genus.

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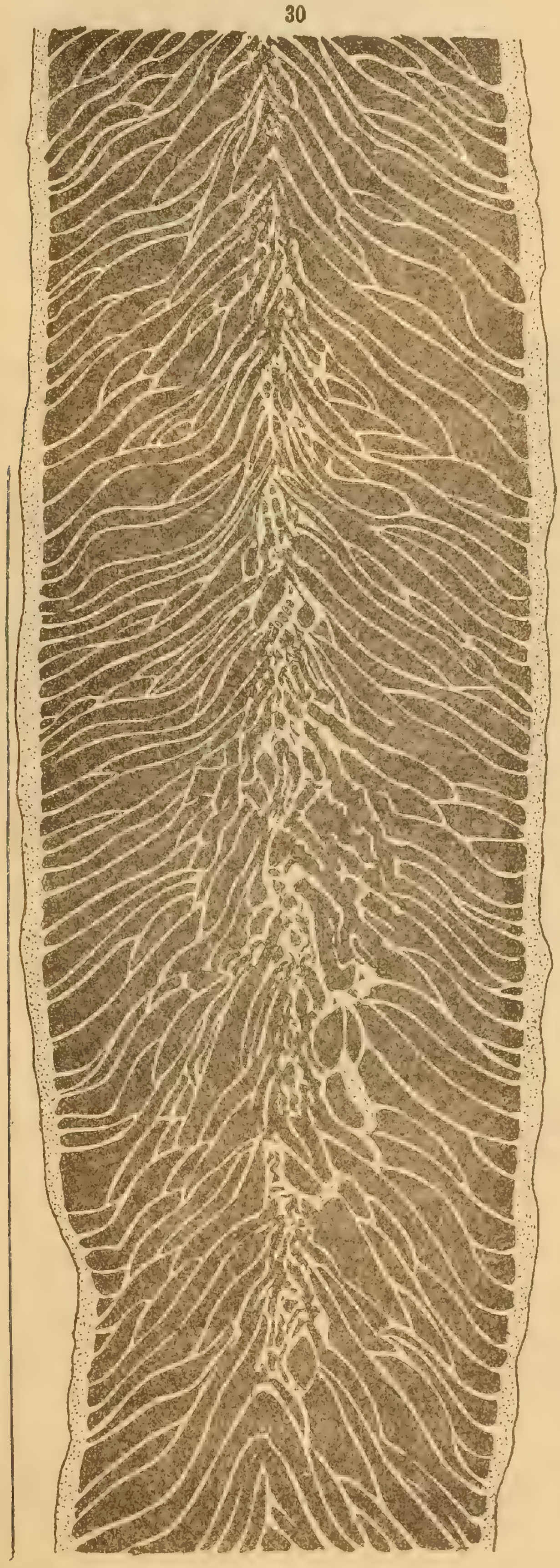

Fig. 30 Scenophyllum conigerum *Rominger*. A longitudinal section showing the conical subcystose tabulae, and pseudocolumella

31

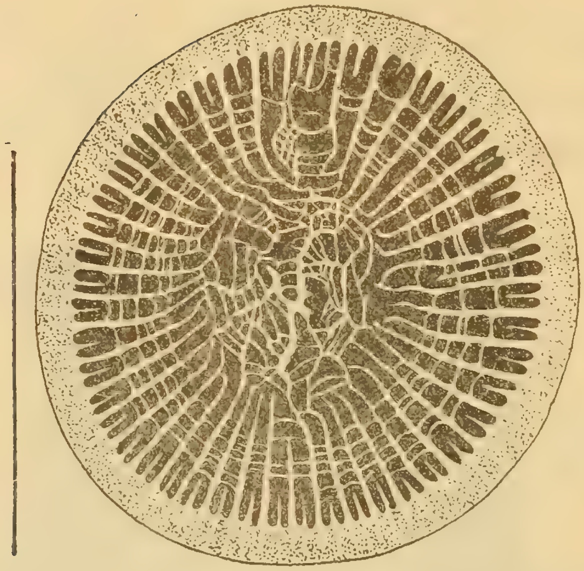

Fig. 31 A transverse section of the same showing septa and dissepiments, and fragmentary edges of tabulae near the center

32

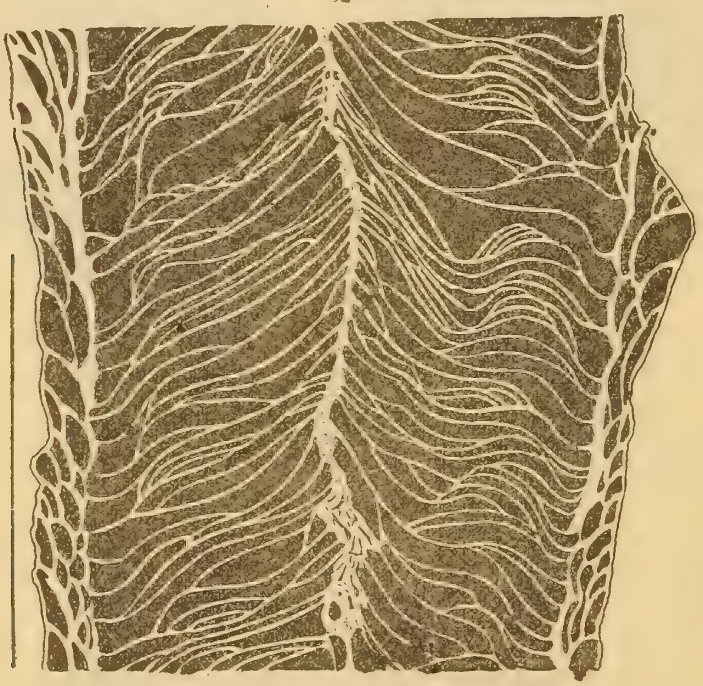

Fig. 32 Clisiophyllum oneidaense *Billings.* A longitudinal section for comparison with fig. 30

SYNAPTOPHYLLUM, *gen. nov.*

Type: *Eridophyllum arundinaceum* Billings, Can. jour. 1859. 4: 134. Onondaga limestone.

Examples: *Eridophyllum simcoense* Billings, Can. jour. 1859. 4: 131.

Eridophyllum stramineum Billings, Can. jour. 1859. 4: 135.

Corallum forming masses composed of slender, elongate, cylindric individuals, subparallel, and connected with each other by radiciform expansions; rapidly increasing by calicinal gemmation; septa alternating in size; the longer ones continuing nearly to the center; their sides carinated as in Heliophyllum; the margins slightly denticulated. Internally there are usually, in the peripheral region, a single row of small cysts, though in portions of the more robust forms there are occasionally two rows. The margins of this row of cysts, in a transverse section, give the appearance of a secondary wall. The tabulae are com-

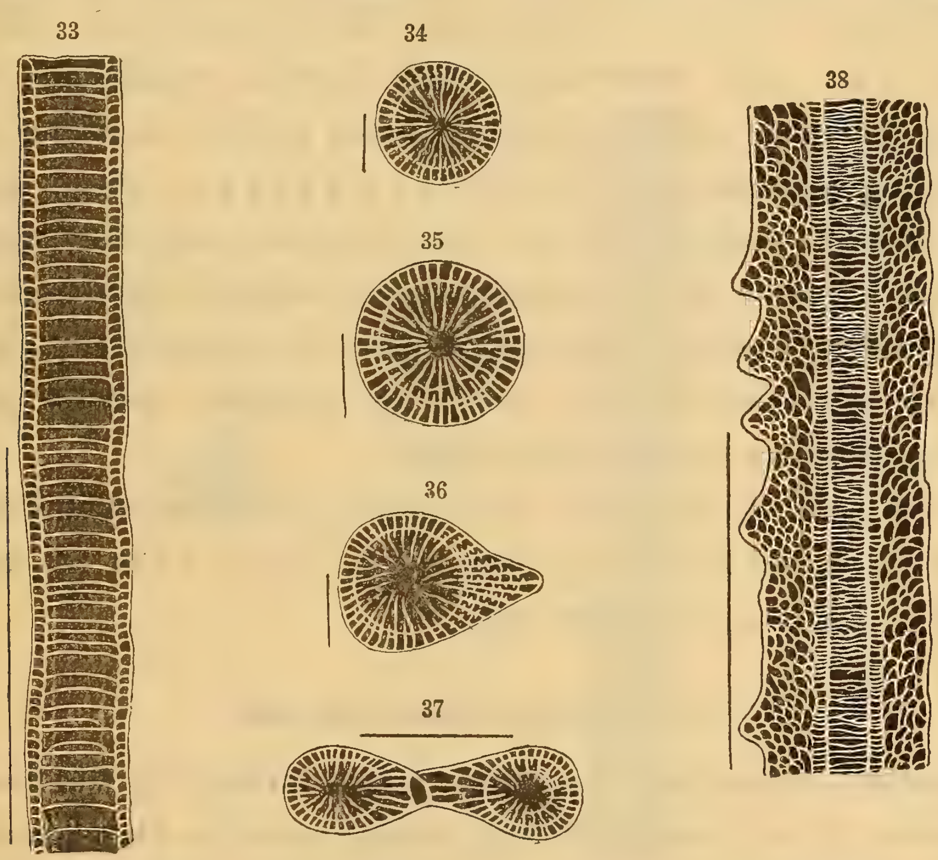

Fig. 33 Synaptophyllum simcoense (*Billings*). Longitudinal section showing single row of cysts, and wide tabulae, enlarged
34 Transverse section, showing crenulated septa, enlarged
35 S. baculoideum *sp. nov.* A transverse section showing septa, and vertical rows of cysts resembling an internal wall, enlarged
36 Transverse section showing radiciform expansion, enlarged
37 S. segregatum *sp. nov.* Transverse sections showing coalescing radiciform expansions, enlarged
38 Eridophyllum rugosum *E. and H.* A longitudinal section for comparison with Synaptophyllum

paratively strong, occupying the greater portion of the width of the interior.

There has been much confusion in regard to the forms now brought together in this genus. Billings (*loc. cit.*), Davis (*Ken-*

tucky fossil corals) and others, have included them in the genus Eridophyllum *E. and H.*; while Rominger (*Geol. sur. Michigan*, 1876) considers Eridophyllum a synonym of Diphyphyllum *Lonsdale*, and places these forms in the latter genus; but Frech in Roemer's *Lethaea Palaeozoica* p. 356, speaking of Eridophyllum, says: "Lonsdale's genus Diphyphyllum in fact embraces corals of the Carboniferous limestones of a very different structure."

The forms included in the genus Synaptophyllum have generally been considered of the same character as Eridophyllum verneuilianum, E. rugosum, E. huronicum, etc. Externally they have a superficial resemblance, but may easily be distinguished by the character of the radiciform expansions. In Eridophyllum these are flat, proceed from one side of the coral only, and are not connected with the interior of the adjacent coral; while in this genus they are cylindric, proceed from all portions of the coral, and usually the expansions of adjacent corals are opposite, meeting and coalescing midway between the corals.

Eridophyllum is a valid genus, including such forms as E. verneuilianum *E. and H.*, E. rugosum *E. and H.*, E. huronicum *Rominger*, etc.

SCHOENOPHYLLUM, *gen. nov.*

Corallum consisting of a large mass, formed by the close aggregation of very long cylindric stems; exterior with strong concentric wrinkles of growth and conspicuous costae. There are frequent slender processes from the coral, about 3 or 4 mm in length, regularly diminishing in size to the extremity, ascending, continuing to the adjacent corallum and serving as supports.

The gemmae spring from the margin of the calyx, the parent corallum continuing growth, thus giving to the younger corals the appearance of proceeding from the side of the parent corallum at a great distance from the calyx; septa comparatively few in number; alternate septa inconspicuous, often apparently obsolete; cardinal septum continuing a short distance beyond the

center, usually becoming much enlarged at the extremity, which has the appearance of a solid, compressed columella, but sometimes the extremity of the septum is but slightly, if at all, enlarged. Internally in the peripheral region there is a single row of comparatively large cysts. In a transverse section the edges of the cysts give the appearance of a continuous inner wall. The tabulae are broad, usually ascending to the center.

In the collection of Prof. Hall this form has been labeled Lithostrotion harmodites. I have seen no authentic specimens of that species, but on comparison with the illustrations given by Edwards and Haime (*Monographie des polypiers fossiles.* pl. 15, fig. 1, 1[a]) it is evident that the identification is wrong. In that species the columella is solid, unconnected with the septa; while in this the so-called columella is formed by the enlargement of the extremity of the cardinal septum, as in Lophophyllum.

40

39

Fig. 39 Schoenophyllum aggregatum *sp. nov.* Transverse section showing the enlarged extremity of the cardinal septum, and apparently an inner wall, enlarged

40 Longitudinal section showing a single row of cysts, tabulae, and the enlarged extremity of the cardinal septum, enlarged

Placophyllum, *gen. nov.*

Type: *Placophyllum tabulatum* sp. nov. Onondaga limestone.

Corallum consisting of large masses, composed of loosely aggregated, greatly elongate, cylindric stems, of rigid appearance, which in the type species have a diameter of from 8 to 10 mm; exterior with numerous wrinkles of growth; costae distinct.

At infrequent intervals there are slender lateral processes, which continue to the adjacent coral and serve the purpose of supports.

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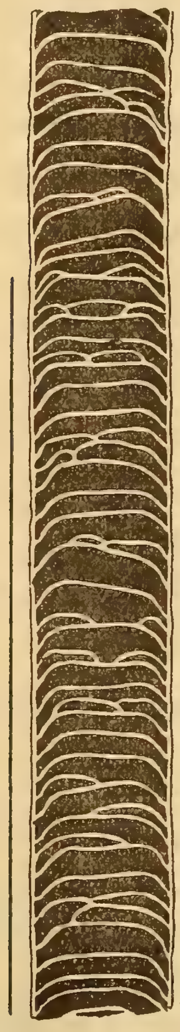

Fig. 41 Placophyllum tabulatum *sp. nov.* A longitudinal section showing the tabulae occupying the whole of the internal cavity

Internally the cysts are absent, the whole interior being occupied by strong, broad tabulae.

The internal structure closely resembles that of Amplexus, but the entirely different manner of growth would separate it from that genus. The type species, externally, most closely re-

sembles Cylindrophyllum elongatum. The manner of growth is similar, both consisting of an aggregation of elongate, cylindric stems, but in that species there are numerous cysts as well as tabulae, the structure being heliophylloid. From the other forms, which consist of an aggregation of cylindric stems, specially some forms of Synaptophyllum to which it has a resemblance, it may always be distinguished by its internal structure.

CYLINDROPHYLLUM, *gen. nov.*

Type: *Cylindrophyllum elongatum* sp. nov. Onondaga limestone.

Colonies forming masses composed of loosely aggregated, very

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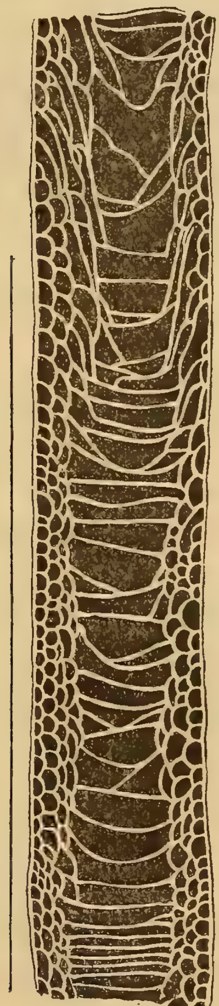

Fig. 42 Cylindrophyllum elongatum *sp. nov.* A longitudinal section showing internal structure

elongate, cylindric stems, in the type species having a diameter of from 12 to 14 mm; distance between the corallites variable;

they are sometimes in contact, at other times distant the diameter of an individual or more; exterior with annulations and wrinkles of growth; costae distinct; alternate septa very short; sides of septa carinated as in Heliophyllum, but their margins very seldom denticulate. Internally the peripheral region is occupied by cysts, which in a longitudinal section have the appearance of being arranged in vertical rows; tabulae strong, usually horizontal, and at varying distances apart.

In the type species the corallites are straight and rigid, and I have observed no lateral excrescences or expansions.

The internal structure of this genus is essentially the same as in Heliophyllum, but the manner of growth and general appearance is such that it could not be included in that genus.

In a longitudinal section the structure appears similar to that of the more robust forms of Synaptophyllum. In a transverse section the appearance is very different. Externally it may be easily distinguished from that genus by the absence of the lateral processes, which are a distinguishing feature of Synaptophyllum.

In exterior it resembles Placophyllum, but differs in internal structure.

PRISMATOPHYLLUM, *gen. nov.*

Type: *Prismatophyllum rugosum*, E. and H. Monographie des polypiers fossiles. 1851. p. 387, pl. 12, fig. 1, 1^a, 1^b, and *Cyathophyllum rugosum*, Rominger, Fossil corals. 1876. p. 166.

Example, *Acervularia davidsoni* E. and H. Monographie des polypiers fossiles. 1851.

Colonies forming masses composed of prismatic corallites, in contact with each other, and of essentially the same diameter for their entire length. While the internal structure of the genus is very similar to that of Heliophyllum, the prismatic form, mode of growth and reproduction are so widely different from the typical forms of that genus that they should not be included in the same genus.

The typical species of this genus, P. rugosum, is the same as that described by Milne-Edwards and Haime and by Rominger as Cyathophyllum rugosum, they citing

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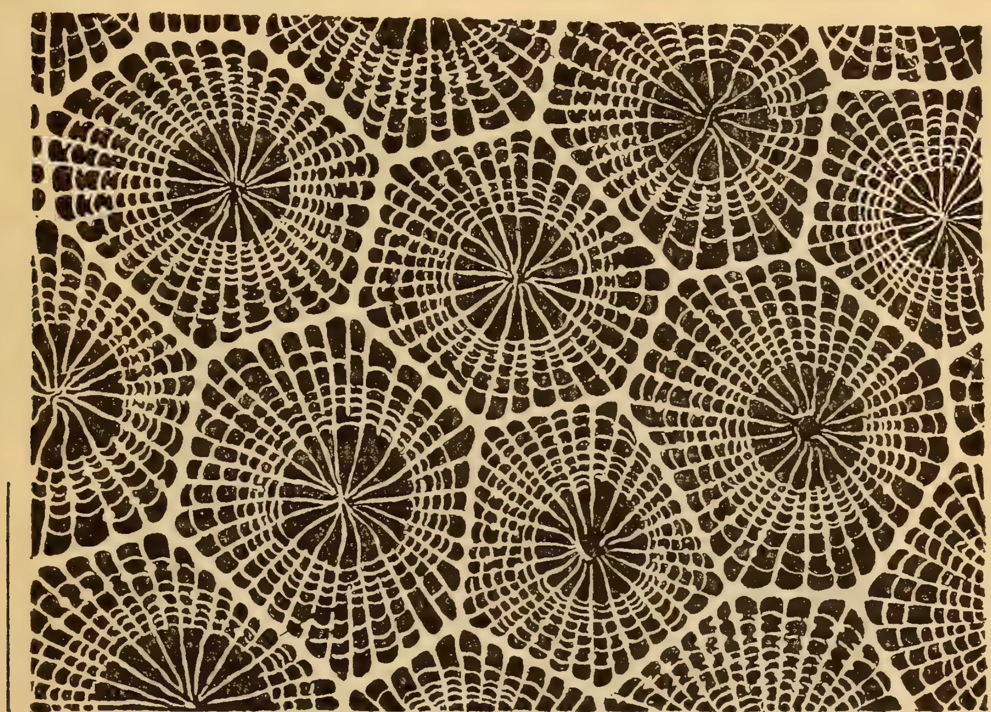

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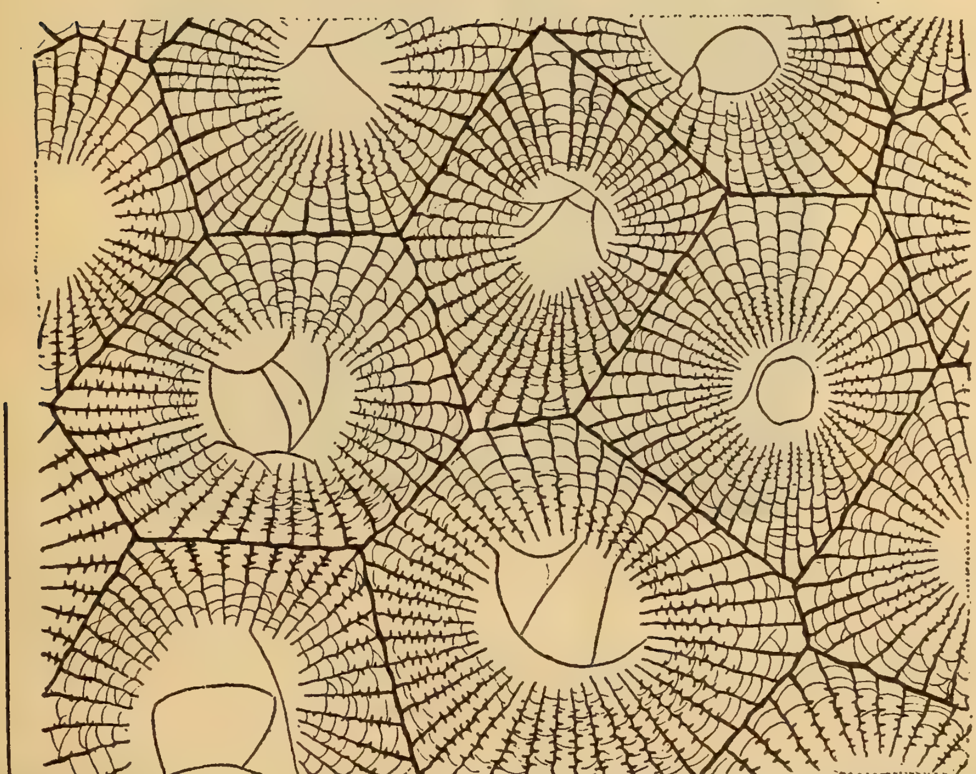

Astrea rugosa *Hall*, as a synonym. I have before me the specimen of Astrea rugosa from which the original description and drawing were made, and it is very clearly a Phillipsastrea.

Edwards and Haime (*Monographie des polypiers fossiles.* 1851. p. 418), in the description of Acervularia davidsoni, speak of the interior wall, but those forms which in this country have been generally considered as A. davidsoni do not have

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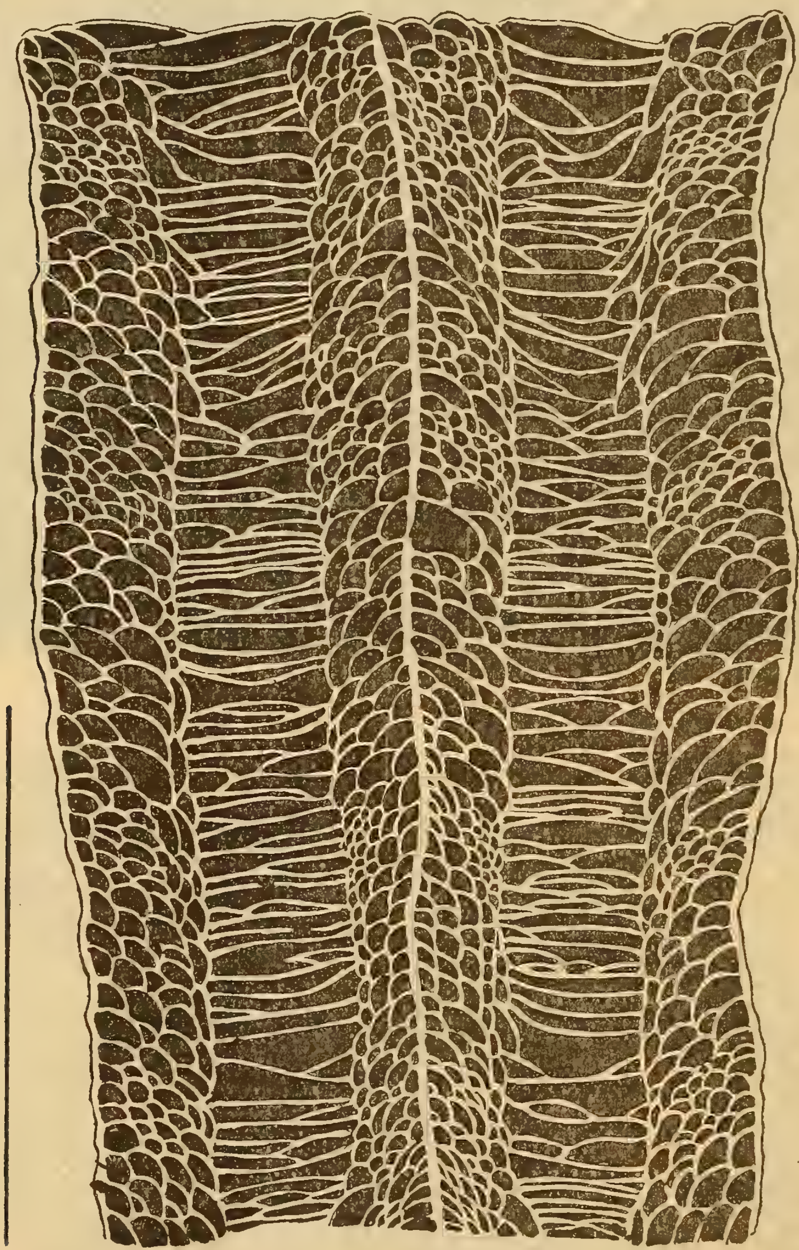

Fig. 43 Prismatophyllum (davidsoni) *E. and H.* Transverse section showing prismatic form, the septa, and the cut margins of cysts, enlarged
44 P. rugosum *E. and H.* Transverse section showing polygonal form of corallites and denticulated septa, enlarged
45 Longitudinal section showing internal structure

an interior wall, though in a transverse section the abrupt ending of the cysts, or dissepiments, coincidentally with the shorter septa gives the appearance of an interior wall. The continuation of alternate septa to the center proves that there is no secondary wall.

HOMALOPHYLLUM, *gen. nov.*

Type: *Zaphrentis ungula* Rominger, Fossil corals. 1876. p. 151. Onondaga limestone.

Example: *Zaphrentis herzeri* Hall. Fossil corals Niagara and Up. Held. groups. 1882. p. 35.

The above species have a decided characteristic in that they are flattened on the side of the greatest curvature; for some distance from the apex they are concave; calyx oval, with one side straighter than the opposite side. The form of the corallum is similar to that of Calceola. They make a natural group which differs from Zaphrentis and should be removed from that genus.

EDAPHOPHYLLUM, *gen. nov.*

Type: *Cystiphyllum bipartitum* Hall. Onondaga limestone.

In form and general appearance similar to Coleophyllum, though the calyx is much less oblique. The conspicuous septal of that genus is replaced by an abnormally developed cardinal septum, which is here the most conspicuous feature.

Internally the structure consists of a series of laminae usually separated by cysts. It also resembles that of Coleophyllum, but the cysts are more highly developed.

Etymology of generic terms

Charactophyllum. *Χăρακτός*, toothed, saw edge, and *φύλλον*, a leaf, in allusion to the serrated margins of the septa.

Cylindrophyllum. *Κύλινδρος*, a cylinder, and *φύλλον*, a leaf, in allusion to the form of the corallites.

Ditoecholasma *Δίς*, double, *τοιχος*, a wall, and *φύλλον*, a leaf, in allusion to the outer and inner walls.

Edaphophyllum. *῎Εδαφος*, a base, foundation, and *φύλλον*, a leaf, in allusion to the laminate base of the calyx.

Enterolasma. *῎Εντερον*, intestine, and *῎Ελασμα*, a plate, in allusion to the convoluted center of the coral.

Hapsiphyllum. *Ἁψίς*, an arch, and *φύλλον*, a leaf, in allusion to the arched accessory wall.

Homalophyllum. *῾Ομăλός*, level, and *φύλλον*, a leaf, in allusion to the flattened portion of the coral.

Kionelasma. *Κίων*, a column, and *''Ελασμα*, a plate, in allusion to the prominent pseudocolumella.

Laccophyllum. *Λάκκος*, a well, and *φύλλον*, a leaf, in allusion, to the appearance of the central area of the coral in longitudinal section.

Lopholasma. *Λόφος*, a crest, and *''Ελασμα*, a plate, in allusion to the carinae of the septa.

Meniscophyllum. *Μηνισκος*, a crescent, and *φύλλον*, a leaf, in allusion to the form of the pseudocolumella.

Odontophyllum. *'Οδόντος*, a tooth, and *φύλλον*, a leaf, in allusion to the denticulate margins of the septa.

Placophyllum. *Πλάξ*, anything flat or broad, *φύλλον*, a leaf, in allusion to the broad tabulae.

Scenophyllum. *Σκῆνος*, a tent, and *φύλλον*, a leaf, in allusion to the tent-like appearance of the tabulae.

Schoenophyllum. *Σχοινος*, a rush, and *φύλλον*, a leaf, from the appearance of the corallites.

Sterelasma. *Στερεός*, firm, solid, and *ἔλασμα*, a plate, in allusion to the filling of the central area of the coral with stereoplasma.

Synaptophyllum. *Συναπτός*, joined together, *φύλλον*, a leaf, in allusion to the lateral processes connecting the corallites.

Triplophyllum. *Τριπλόος*, triple, and *φύλλον*, a leaf, in allusion to the three septal foveae.

SILURIC FUNGI FROM WESTERN NEW YORK

BY FREDERIC B. LOOMIS (Amherst Mass.)

Plate 16

At about the middle of the Clinton group as it is developed at Rochester N. Y., occurs a band of hemate containing numerous fossils, which give evidence of having been deposited in a moderate depth of water. In thin sections many of these fossils are found to be more or less perforated by fine tubules entering from their surfaces. The borings are of interest as additional testimony of the presence of plants during Clinton time, a period when plants were very sparsely represented.[1] The borings, as will be seen from the figures, enter from the surface and are believed to represent plants which grew on the shells and sent only a part of their filaments into the shell. The tubules penetrate a little way into or occasionally riddle the whole shell. The borings are uniform in size, there being no tendency to irregular swellings in places where the host material was softer. At the ends of certain tubules are spherical swellings, in most cases of uniform shape and size. These swellings may represent sporangia, though I have no conclusive evidence to that effect. The borings doubtless represent the work of the mycelium of a fungus, probably some member of the Phycomycetes. I regard them as due to fungi rather than to algae for the following reasons: the tubules are quite uniform in size and shape; while those of algae, under the same conditions, are more or less irregular; there is also in these fossils no evidence of septa, in which respect they are more like fungi than algae. The tubules are very small, $\frac{1}{400}$ to $\frac{1}{500}$ mm in diameter, which is smaller than is usual for algae, but quite normal for the mycelia of fungi. The spherical inflations at the ends of some filaments are very like sporangia, or other fungous swellings; but not at all like

[1] Bythotrephis, which is common in the rocks of this age and has usually been looked on as algous, is regarded by Rothpletz and others as a sponge.

swellings of algae, which are usually quite irregular in size and shape. Such spherical swellings as I have figured on the ends of various hyphae have been frequently described[1] on hyphae which had penetrated into the wood or leaves of fossil plants. Indeed, the appearance of the large number of filaments, entering from the surface and penetrating a short distance into the calcareous shells, is very like that produced by the mycelium of a lichen in penetrating a limestone or other rock on which it grows.

It is difficult to refer these marine fungi to modern families, as such recent fungi have not been extensively studied except so far as they affect food fish, etc. The mycelia from the Clinton group may be safely called Phycomycetes, and are probably to be placed near the genus Saprolegnia. Duncan[2] has described similar borings under the name Palaeachlya perforans, referring them also as "unicellular algae" to the family Saprolegniae.[3] These were obtained from Lower Siluric foraminifera, the Upper Siluric coral, Goniophyllum pyramidale, the Devonic coral, Calceola sandalina, and a Miocene Thamnastraea. This author did not distinguish species, referring to one species mycelia both coarse and fine from Siluric to Tertiary. In the material under present consideration I find three forms distinguishable both by the character of the mycelium and the spherical swellings. So far as the mycelium is concerned, the Clinton fungi resemble Duncan's Palaeachlya; but the spherical swellings closely resemble those described by Kölliker[4], found in both recent and fossil corals and shells, which fungi Kölliker described but left unnamed. They are also very like the Carbonic genus, Peronosporites,[5] whose hyphae, however, enter plant tissue and would therefore seem to be either fresh-water or aerial fungi. Peronosporites has just such swellings as the Clinton fungi at the ends of small hyphae, both hyphae and swellings being unmodi-

[1] *See* Seward. Fossil plants. 1898. p. 217.
[2] Quart. jour. geol. soc. Lond. 1876, p. 205.
[3] At the time Duncan wrote Saprolegniae were considered algae, but are now classed with fungi.
[4] Zeitsch. Wiss. Zool. 1859. 10: 215.
[5] *See* Seward. Fossil plants. 1898. p. 217.

fied as to shape or size whether in the cell walls or open cell spaces. In spite of the difference of host, for the present I prefer to assign these Clinton fungi to the genus Peronosporites rather than to propose a new generic name on a very inadequate botanical basis. The following three species are based on variations of the mycelium and hyphal swellings. The drawings are made with a camera lucida.

Peronosporites ramosus *sp. nov.*

Plate 16, fig. 1-3

This species is characterized by a mycelium about $\frac{1}{420}$ mm in diameter, which gives off branches freely. All parts of the mycelium are uniform in size. Some hyphae are swollen at their ends into a globular sac. These sacs vary in size from $\frac{1}{75}$ to $\frac{1}{30}$ mm in diameter, and are globular in form, though they may be more or less ovate or even asymmetrical. Rarely a hypha, after enlarging into a sac, continues farther; though in one case a hypha has expanded into a second sac. These more or less irregular swellings probably do not represent sporangia or resting spores, which would be more regular in size and shape.

Peronosporites globosus *sp. nov.*

Plate 16, fig. 4

The mycelium is $\frac{1}{500}$ mm in diameter, enters from the outer surface and branches but very seldom. At the ends of certain short hyphae are spherical swellings about $\frac{1}{35}$ mm in diameter, quite uniform in size and shape. Being uniformly on short hyphae, the swellings are near the surface of the host, and may represent sporangia though no spores are present. This is a common species.

Peronosporites minutus *sp. nov.*

Plate 16, fig. 5, 6

The mycelium, about $\frac{1}{500}$ mm in diameter, entering from the surface, penetrates straight downward into the shell without giving off branches. Frequently on the ends of long hyphae are spherical swellings $\frac{1}{100}$ mm in diameter. These are very regular,

and have the smallest swelling belonging to any species, though the mycelium has a diameter about the same as the foregoing species.

All of the above are found on sectioning the firmer parts of the Clinton hematite layer, which is an aggregation of rolled bits of bryozoa, corals, brachiopod shells and crustacea, each fragment being coated by concentric layers of hematite, making an oolitic structure. If one accepts the theory that all oolites are formed by concentric coatings precipitated by algae, then these oolites must indicate the presence of other plants in the Clinton sea. This oolitic formation is described by C. H. Smyth jr,[1] who carefully describes the process of concentric precipitations, but does not assign algae as a cause. This author describes the conditions prevailing at the time the hematite layer was deposited as a swampy shore of an inland sea.

Such fungi as those above described are common through Mesozoic and Cenozoic time, and have been found at least once before in Siluric beds.[2]

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[1]Zeitsch. f. Praktische geologie. August 1894. *See also* Amer. jour. sci. (3) 43, p. 487.

[2]Kölliker (*loc. cit.*) says he found his Palaeachlya in an Upper Siluric Cyathophyllum and a Lower Siluric foraminifer from Europe, but he does not figure either.

EXPLANATION OF PLATE

Peronosporites ramosus *sp. nov.*

Fig.

1 A transverse section of a punctate brachiopod shell inhabited by P. ramosus. *a*=shell punctae. x150

2 Branch *b* of fig. 1. x625

3 A shell cut parallel to the surface, showing an advanced stage of disintegration caused by P. ramosus

Peronosporites globosus *sp. nov.*

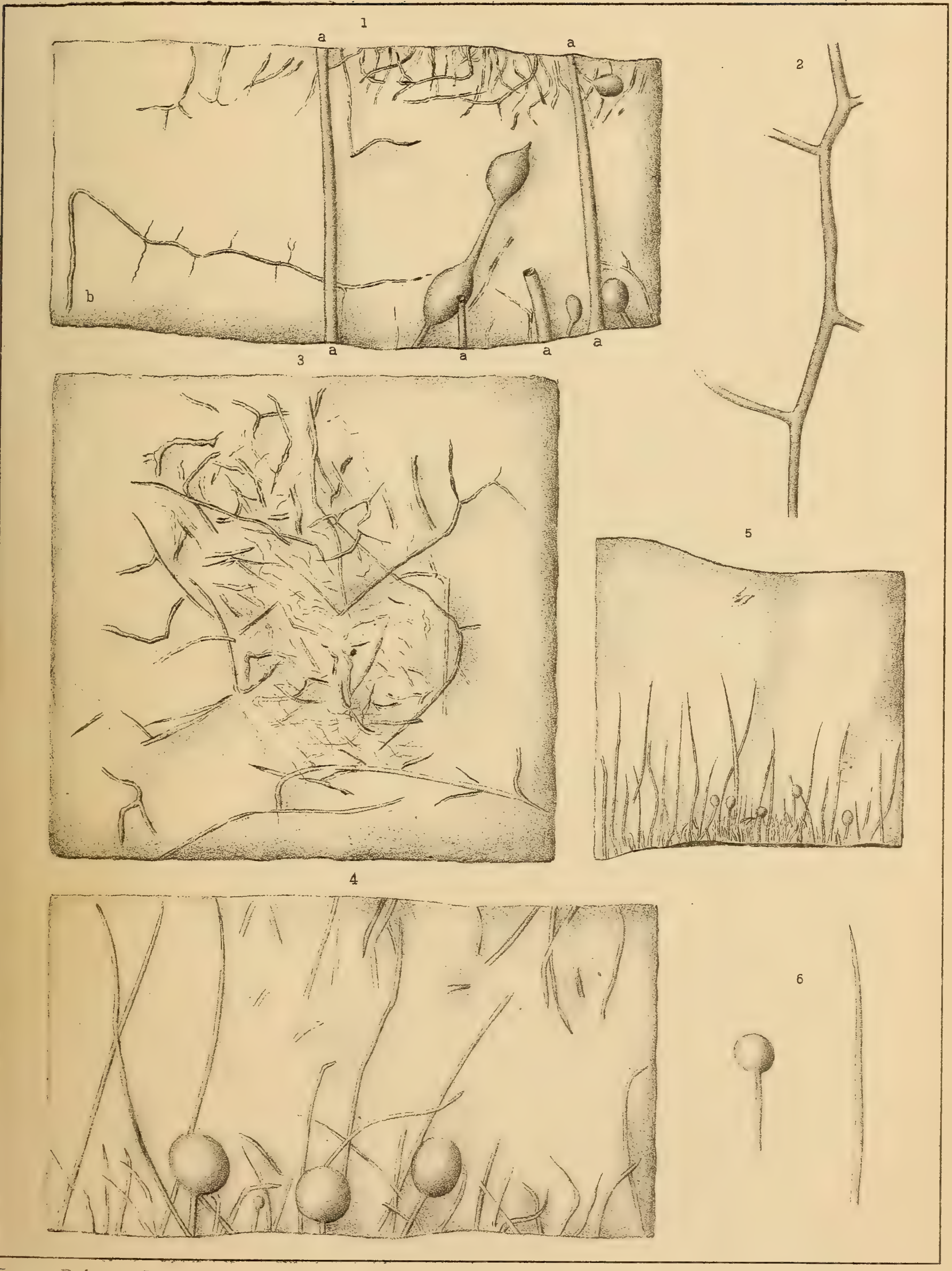
4 An impunctate brachiopod shell inhabited by P. globosus. x250

Peronosporites minutus *sp. nov.*

5 An impunctate brachiopod shell penetrated on one side only by P. minutus. x125

6 *a*, a spherical swelling on a hypha, x500; *b*, a hypha. x500

FOSSIL FUNGI.



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The superior figures tell the exact place on the page in ninths; e. g. 221^3 means page 221, beginning in the third ninth of the page, i. e. about one third of the way down.

(Pages 233–4 were bulletin cover pages)

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FREDERICK J. H. MERRILL *Director*

No. 40 Vol. 8

October 1901

ANATOMY AND PHYSIOLOGY

OF

POLYGYRA ALBOLABRIS AND LIMAX MAXIMUS

AND

EMBRYOLOGY OF LIMAX MAXIMUS

BY

GEORGE B. SIMPSON

Division of paleontology

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1901

CONTENTS

PREFACE

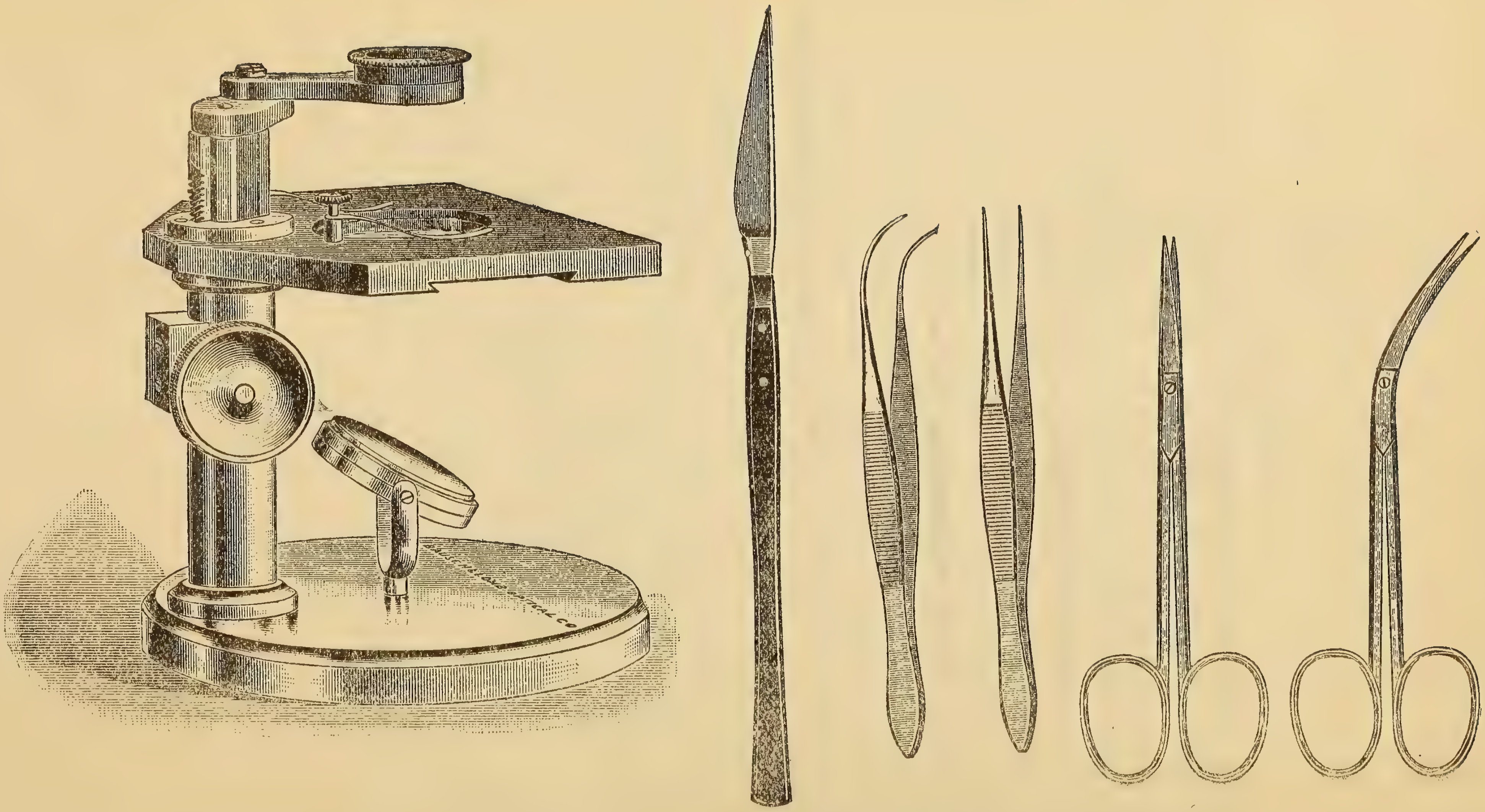
This work has been written for the use of individual students, as well as for classes in schools and colleges. No similar work on the snail has been published in this country, and in my own investigations I have seriously felt the need of one.

I have endeavored to write a work which will enable the student, without a previous knowledge of the subject, satisfactorily to pursue his investigations. I have, therefore, commenced at the beginning, giving explanations in regard to the instruments necessary, methods of dissection, how to collect the animals, etc., followed by a plain, but full, description of all the organs, without the use of too many technical terms, and unencumbered by theories.

I have made very full illustrations of all the organs and parts of organs, enabling the student at once to see their form and position. These illustrations are accurate copies from nature and in no case are they diagrammatic.

The manuscript of that portion of this work treating of anatomy and physiology was kindly reviewed by Prof. H. A. Pilsbry, of Philadelphia, and to him I am indebted for suggestions, specially in regard to nomenclature. I am also indebted to Prof. E. G. Conklin, of the University of Pennsylvania, who reviewed that portion treating of the embryology of Limax.

George B. Simpson



Dissecting microscope and instruments

POLYGYRA ALBOLABRIS AND LIMAX MAXIMUS

INTRODUCTION

Methods and apparatus

Specimens of Polygyra and Limax may be easily kept in captivity by placing them in a box in which there are about 4 inches of earth covered with dead leaves. The earth must be kept moist. The box must be covered with mosquito netting or tarlatan. The mosquito netting will be sufficient for adult individuals, but the young of Limax would escape easily through its meshes.

For the study of the histology and embryology a compound microscope is necessary, with 2 inch, $\frac{2}{3}$ inch and $\frac{1}{6}$ inch objectives. A dissecting microscope is almost indispensable. I have used, for that purpose, one manufactured by Bausch & Lomb of Rochester (N. Y.), known as the "laboratory dissecting microscope," fitted with a Hastings aplanatic lens. A cut of this instrument is given herewith. Two pairs of fine scissors will be necessary, one pair with straight points, the other with curved points; one or more fine scalpels, and two pairs of fine forceps, one straight and the other curved. A pair of stronger forceps and a pair of fine pliers will be needed to remove the shell of Polygyra. Dissecting needles are also necessary. These can be made by forcing the heads of fine needles, by means of a pair of pliers, into the end of a round stick of small diameter. The point of one of these needles should be bent so as to form a hook, first heating the end of the needle to a white heat.

Methods of killing and manipulating

I have tried all of the various methods recommended for killing Polygyra and Limax, and find only one that is uniformly successful, and that is drowning. In using hot water and various chemicals, in nearly every case the animal is more or less contracted, and thus rendered useless for the pur-

pose of a successful dissection. In drowning the animal, I have used a fruit-preserving jar, as being more convenient than a wide-mouthed bottle. The jar should be completely filled with water, so that, when the cover is fastened on, there will be no air space left. The animals being placed in the water and the cover screwed on, the jar should be left undisturbed for 48 hours; it requiring about that length of time to drown the animals. Remaining undisturbed, they will die fully extended; but, if the jar is disturbed in the meantime, more or less contraction will take place. The animal when dead should be thoroughly washed to free it from all adhering mucus, and placed in alcohol diluted with about two thirds the amount of water, additional alcohol being added from day to day till the mixture consists of about 75% of alcohol. The animals should then be removed and placed in undiluted alcohol, when they will keep indefinitely. If placed at once in strong alcohol, the action of the fluid on the integument prevents the proper preservation of the internal organs.

To remove the shell, preparatory to dissecting the animal, break the peristome with a small pair of pliers. The remainder of the shell can be removed with a pair of forceps, carefully breaking off a small piece of shell at a time till it is removed to the apex. The columella can be removed by holding the lower part between the thumb and forefinger of the left hand, and turning the animal with the right. As the columella is like a screw, the animal readily becomes detached by this movement.

In dissecting the animal, a circular china dish about 4 inches in diameter and 2 in depth will be necessary; also a piece of sheet cork as large as will lie at the bottom of the dish, fastened to a thin sheet of lead with either string or rubber bands. It is best to have the lead of the same size as the cork. This leaded cork is to be placed in the bottom of the dish, and the dish filled with alcohol. If the animal has once been placed in alcohol, all dissections should be made in alcohol, but freshly killed specimens may be dissected in water, and many of the organs at this time present a much more natural appearance than when acted on by alcohol. Place the animal on the cork and fasten it down with small pins,

or, better yet, with very fine, short needles, inserted through the margin of the foot. Then, with the fine pair of scissors, commencing at the head, cut through the integument along the center of the back, taking care not to injure any of the organs below. The integument is now to be removed from the dorsal part, turned back and fastened to the cork, removing the needles from the margin of the foot and putting them through the edges of the integument. All the organs of the anterior part of the snail are thus brought into view, and farther dissection of the organs can be intelligently made.

In the case of the Limax nearly all the organs will be brought into view by turning back the integument; but great care must be taken in this genus in cutting through the integument not to injure the pulmonary chamber, as it is situated very near the surface. Also every precaution should be taken that the points of the scissors shall not go below the integument, or the intestine and upper surface of the stomach will be mutilated, and a successful dissection rendered impossible.

Habits

Polygyra albolabris. The snails of this species are found in woods near fields, in ravines and in other situations. They remain concealed through the day when the sun is shining, coming forth for their food toward evening and after showers. It is at these times that they are most easily found during summer. Frequently they may be found on the under side of boards, logs and stones. During cold weather they hibernate, partially burying themselves in the ground, with the apex of the shell downward. At this time they are very easily found by scraping away the dead leaves so as to expose the surface of the ground. While hibernating the animal is completely withdrawn in the shell, the mouth of which is closed by a mucous excretion, which becomes hardened on exposure to the air. It is stated by nearly all writers on this subject that there is always a perforation in this membrane to allow the passage of air; but I have observed numerous cases where the membrane was entire.

Limax maximus is found in gardens, where it is very destructive to vegetation. During the day it secretes itself; but it may easily be found, by the aid of a lantern, while feeding at night.

POLYGYRA ALBOLABRIS *Say, sp.*

Shell

The shell of Polygyra is turbinate, spiral; consisting in P. albolabris of five volutions, coiled around a hollow axis known as the columella. The columella is open at the base in immature specimens, but in adults it is closed by a growth of the shell. When the shell emerges from the egg, it consists of one volution only. Farther growth of the shell takes place in the manner hereafter described.

The shell consists of three parts or layers: the outer commonly, but wrongly, termed the epidermis—cuticle or Carpenter's name, periostracum, is preferable; next a prismatic part; finally a laminate part. The prismatic and laminate layers are of about equal thickness, and together form the greater part of the entire thickness of the shell.

The cuticle is thin; in P. albolabris yellowish brown in color. It is without sensation, like the human scarf skin. Its office is to protect the shell from chemical action, which otherwise would injure or destroy it. After the death of the animal it fades and becomes brittle, or is entirely destroyed in situations in which during life it would not be affected.

The shell is formed by the thickened margin of the integument covering the visceral mass. According to Carpenter, "the shell, as before stated, is formed by the mantle of the shellfish, indeed, each layer of it was once a portion of the mantle, either in the form of a simple membrane or as a layer of cells, and each layer was successively calcified (or hardened by carbonate of lime) and thrown off by the mantle to unite with those previously formed." According to Huxley, the shell growth is not a case of conversion but of excretion, and the shell is built up by successive excretions of membranous laminae, in which granules of carbonate of lime are deposited.

The prismatic part of the shell is apparently formed by the deposition of calcareous matter in prismatic, generally hexagonal, cells, which are themselves formed by the successive secretions of fenestrated laminae, deposited by the margin of the mantle (pl. 2, fig. 12 and 15).

The laminar part is apparently composed of numerous thin laminae varying in thickness. In many thin sections which I have examined under the miscroscope I have seen no trace of the prismatic structure in this part of the shell. The nacreous layer is very thin, forming the inner stratum of the shell, and is of a somewhat pearly appearance. This layer is a part of the laminar stratum, though it seems to be discernible, and in the broken edges of the shell is always distinct and is distinguished by its lighter color.

Till the shell reaches maturity the margin is very thin; but when mature the margin becomes greatly thickened and reflected, forming a broad peristome (pl. 1, fig. 3, 4-7, 12). It is apparently formed by the part of the mantle depositing the prismatic layers, as nearly its entire thickness is of prismatic structure (pl. 2, fig. 13, 14).

If the margin of the shell is broken, it can be repaired by the animal; but, if any other part of the shell is broken, complete renewal is impossible, as the prismatic and cuticular layers of the shell are deposited only by the thickened border of the mantle. A mucoid substance in such cases is excreted and becomes calcified, taking the place of the missing shell; but any considerable breakage of the shell, except at the margin, is liable to be fatal to the animal. In collecting specimens, sometimes by accident the shells were broken; in nearly every case the animals died within a few days.

External features

The ventral part of the animal is expanded into a locomotor organ or foot, which is a thick, vermiform body with a ribbon-like ventral disk. The head is situated at the anterior extremity, and is obtuse; from it protrude two pair of tentacles, the upper

and much the longer pair containing the eyes, the lower and shorter pair, the olfactory nerves. The mouth is situated at the anterior basal part of the head. Immediately below it is the opening into the pedal gland. The anterior upper part of the body is rounded; the posterior part is more acute.

The dorsal part of the animal is produced in a spirally coiled mass, containing the whole of the digestive gland, and parts of the alimentary, circulatory and reproductive organs, and is therefore known as the visceral mass.

The integument of the foot consists of a thick mucous-secreting membrane, with a muscular substratum. There are numerous mucous glands occupying nearly the whole of the membrane. The muscular substratum consists of unstriped fibers, arranged longitudinally, transversely and obliquely. Interior to this investment of the foot is a muscular membrane inclosing the digestive and reproductive organs, which is sometimes called the peritoneum.

The dorsal part of the animal is inclosed in the shell and is an exact mold of the shell. The integument of this part is very thin and semi-transparent and is known as the mantle. Where the visceral sac joins the foot the mantle is very much thickened, forming a muscular collar, which is the shell-building organ of the animal.

When the animal is at rest or alarmed, the foot is contracted entirely within the shell, occupying the space at other times filled by the pulmonary cavity. The pulmonary chamber is very large and is situated in the outer part of the lower whorl. When the foot is protruded, the pulmonary rete still remains in contact with the shell, thus leaving a large cavity. It is into the space obtained by the collapse of this cavity, when emptied of air, that the animal withdraws when contracted. Thus the pulmonary chamber of testaceous snails is as much larger than the chamber of the naked slugs, as the volume of the foot superadded.

Movement

The snail moves with a slow, gliding motion, produced by the muscles of the pedal disk. First the hinder part of the foot is drawn up, and the part immediately anterior to it is extended. This part is then contracted, and the part immediately anterior to it extended. These movements take place the entire length of the body, following each other so quickly that a gliding motion is produced. This contraction and expansion are confined to the central part of the pedal disk, the margins of the foot having a lateral undulating movement of their own.

The movement of the muscles of the middle part of the pedal disk gives rise to a very peculiar appearance, as if there were a channel through which oval drops of a transparent fluid were rushing in quick succession. Each contraction and expansion of the muscles of each part of the disk give the appearance of one of these drops of fluid, and, as these movements take place in rapid succession along the whole length of the foot, beginning at the posterior and continuing to the anterior extremity, the optical delusion of rushing drops of water is created.

If a snail is placed on a thin piece of glass, and the under part is observed while the snail is in motion, this movement can be observed, or if a Limax is held with the fingers in such a position that the under part of the body is uppermost, when it struggles to escape the appearance is the same, the action of the muscles being the same as when the animal is in actual motion.

Food—carnivorous habits

The snails which I have kept in confinement for three years have been fed on apples and lettuce, and occasionally cabbage. At first I placed lettuce in the box, but they refused to eat it. After several days I placed pieces of apple in the box, and these they ate ravenously. I fed them on apples for a month or more, when they seemed to tire of them and refused to eat. After a little time I placed lettuce in the box; this they ate, and since that time it has been their principal food.

The popular belief that snails will feed on almost any vegetable is erroneous. I find that they are very particular regarding their food. I have placed spinach, young beet leaves and several other kinds of tender vegetables in the box, but they have refused to eat them.

Binney speaks of the carnivorous habits of Circinaria concava, and also speaks of Polygyra sayi devouring its own species. John Walton, in *Mollusca of Monroe county*, says of the cannibalistic habit, in some of the species: "I had abundant evidence the past summer in the Zonites fuliginosa; fully one third of the specimens of this species, taken during a special search by myself and pupils, were found devouring shells and animals, sometimes their own species, but more frequently the young of P. albolabris, thyroides, sayi, and Triodopsis palliata. This was in July, and possibly the time of the year had something to do with the habit, as in the case of some seed-eating birds that are known to consume large quantities of insects in feeding their young and probably themselves during the breeding season".

I would suggest, in regard to their carnivorous habits, that, if the season was very dry, there may have been a scarcity of suitable vegetable food. I have raised over six hundred specimens from the egg, and I have found that, when the adult animals were plentifully supplied with food, the eggs and young were perfectly safe. When returning from my vacation, I packed many specimens of P. albolabris in a box of dead leaves; in a small box I had several hundred eggs and very small young. Several days elapsed before I could attend to them. I then procured a box, placing several inches of earth in the box, covering it with dead leaves, and placed the larger shells on the leaves. Then I busied myself with the eggs. Some that were just hatching, partly out of the shell, I reserved to put in alcohol. The others I laid temporarily on a piece of paper in the box with the larger shells. After putting the specimens in alcohol I returned to the box, and was surprised to see several of the adults busily

engaged in devouring the eggs; but I attributed this to the fact that many of the specimens, procured by me at the St Lawrence river, owing to the exceedingly dry season, had been without food for several weeks. I very much doubt that they are ever carnivorous when furnished with an abundance of vegetable food. The immunity of the eggs and young in a box with more than a hundred adult specimens would seem to prove this.

Since the above observations were made two years have elapsed, and during that time I have raised many species, both of Polygyra and Limax, from the egg to maturity and have noticed no carnivorous habits, though some of the smaller forms of Limax and Polygyra have been raised in the same box as the large Limax maximus, and some of the latter had a length of 4 inches. In the same manner the smaller species of Polygyra have been safely raised with P. albolabris. The newly hatched young fed principally on the softer parts of the dead leaves in the box, skeletonizing them.

I do not know the exact time elapsing between the laying and the hatching of the egg, but it is certainly less than three weeks. When on a visit to the St Lawrence river in August, I collected several specimens and placed them in a box with moist earth covered by dead leaves. When, three weeks afterward, I took the specimens from the box, I found several groups of eggs, in two of which the young were just emerging from the shell.

There seems to be no uniform time for the laying of the eggs. I have had a large number of specimens in captivity for three years, and at almost any time eggs and newly hatched young could be found in the box. In some specimens collected in the winter, while hibernating, well developed eggs were found in the uterine canal.

Digestive system

The mouth is situated in the anterior part of the foot, and is bounded by thick, fleshy lips (pl. 5, fig. 1). These lips are divided into the upper, lower and lateral. The upper lip is composed of five lobes or divisions situated side by side. The lower lip has

four divisions, of which the two lesser are situated above the two larger divisions. The lateral lips are each entire, comparatively large and somewhat crescentiform.

The mouth leads into an organ known as the buccal body (pl. 4, fig. 1). This organ is somewhat irregularly oval-shaped, and contains the masticatory organ known as the radula (pl. 4, fig. 3).

Just within the upper lip is the crescentiform, corneous lamina, known as the "jaw" (pl. 5, fig. 2), reddish brown in color, and occupying the position of an upper jaw. On the outer face of the jaw are 12 vertical ridges, with pointed ends, which project beyond the lamina. The ridges with their pointed ends closely resemble teeth. The jaw is attached to the buccal body by a band of muscular fibers, inserted in its upper convex edge. During feeding the jaw projects beyond the lips, which are protruded, having the appearance of a prehensile proboscis, which takes hold of the food and draws it to the mouth, the jaw cutting it into small pieces, acting as a chopping knife.

The food now passes into the buccal body. A reference to the figures on plate 4 will give a clear idea of the structure of that organ. The outer walls are thick and are composed of constrictor muscular fibers. On the floor of this organ are two gristly elevations, known as the odontophoral cartilages, which have, attached to their lower parts, small muscles arising from the side walls of the buccal body. Resting on the odontophoral cartilages is a cushion-shaped elevation, inclosed in a mucous membrane, known as the odontophore. Overlying this is the lingual ribbon, or radula, which is studded with an immense number, some fifteen thousand, of small teeth or denticles, arranged in transverse and longitudinal rows.

The teeth preserve the same form throughout in a longitudinal line. The central line always differs from the others, and they gradually vary in form and size, as they pass from the central line laterally. The radula, or lingual ribbon, takes its origin in the sac of the radula (pl. 4, fig. 3, 4), which projects from the lower posterior part of the buccal body, continuing anteriorly from the radular sac upward to the dorsal part of the buccal body,

then curving downward. It is connected by muscles with the floor of the buccal body. Within the sac of the radula and immediately anterior to it, the teeth are immature, in the posterior part of the sac consisting of very minute papilla-like elevations, each arising from a single cell. At the central part of the radula the teeth or denticles are fully developed. Anteriorly they are worn down, in some cases becoming smooth. During feeding the radula is moved forward and backward by the action of the muscles, acting as a rasp to triturate the food.

In addition to the muscles already mentioned, the following muscles are connected with the buccal body (pl. 4, fig. 4, *14*): the buccal retractors, which have their origin, in common with the tentacular muscles and the retractor muscles of the foot, at the columella, and are inserted, as wide bands, in the posterobasal and the posterolateral parts of the buccal body. Numerous small muscles proceed from the buccal body to the integument of the lips (pl. 4, fig. 1, *9*). There are two delicate muscles proceeding from the sides of the buccal body (pl. 4, fig. 1, *8*), which, passing forward and downward, are inserted in the cephalic integument. Two broader bands of muscles, arising from the base of the buccal body, below the muscles just mentioned, proceed laterally, and are inserted in the integument (pl. 4, fig. 1, *7*). A pair of very delicate muscles arise from the posterolateral part of the buccal body, and, passing along its sides, are inserted in the cephalic integument (pl. 4, fig. 1, *6*).

The esophagus takes its origin in the dorsal-posterior part of the buccal body, and consists of a tube passing straight back between the supra and infra-esophageal ganglia (pl. 4, fig. 1, 2, 4), the commissural cords connecting the ganglia bounding it. The esophagus dilates and forms what is known as the crop. The membrane of the esophagus, as well as that of the crop, is very thin, and consists of a columnar epithelium and a basement membrane.

The columnar cells of the epithelium are long and pyramidal, broad at the base and very narrow at their attached parts. They are filled with fine, granular matter, and have each a nucleolated nucleus. Internally there are longitudinal folds of the membrane.

The crop is elongate oval (pl. 5, fig. 3, 4), having a diameter three or four times that of the esophagus. Exteriorly it has a somewhat plicated appearance, caused by the longitudinal folds of the interior. It is situated in the first volution alongside of a part of the spermatic duct.

On each side of the crop are situated the salivary glands (pl. 5, fig. 3, 4). They are elongate, somewhat oval, and arborescent in appearance. They extend nearly the entire length of the crop. They are white in color, and under the magnifying glass present a beautiful appearance. They are composed of lobules, which are the dilated beginnings of the ducts, lined with cells oval in form and having a nucleolated nucleus. The glands are connected with the mouth by ducts, which extend alongside the esophagus. They are cylindric and conspicuous (pl. 5, fig. 3).[1]

The stomach begins almost immediately at the termination of the crop (pl. 5, fig. 3). At first it is small, but little greater in diameter than the esophagus, but rapidly and regularly increases in size nearly to its extremity. A transverse section is circular in outline. The anterior part is situated in the first volution of the shell, lying alongside the spermatic duct, continuing, having on one side the larger lobe of the digestive gland, and the albumen gland, on the other side being in contact with the hermaphroditic duct. It continues to the superior or smaller end of the digestive gland and ovotestis, where it bends somewhat abruptly downward and backward, giving origin to the intestine. Its walls are apparently striated and very thin. The contents of the stomach can be seen through the walls. For illustrations of the crop and intestines *see* plates 5, 6, 10 and 14.

The intestine is of about the same diameter as the esophagus. Immediately on leaving the stomach, it turns backward below the stomach to the large lobe of the digestive gland, following the

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[1] According to A. B. Griffiths (*Phys. invert.* p. 109), the following constituents are found in the salivary secretions: soluble diastatic ferment, capable of converting starch into glucose, calcium, chlorin and doubtfully sulfocyanates and calcium phosphates. In the branchiate Gasteropoda the latter two substances occur, as well as mucin, but doubtfully chlorin.

lateral and posterior border of that gland, then, turning, it proceeds forward and downward on the outer part of the digestive gland, approaching very closely to the first part of the intestine at a short distance from the stomach; then, turning, it proceeds upward and backward through the digestive gland to the border of the pulmonary sac. In its course through the digestive gland it forms an exaggerated letter S (pl. 5, fig. 3; pl. 6, fig. 7, 8).

The rectum continues along the border of the pulmonary sac to the anus, which is situated near the respiratory orifice (pl. 5, fig. 3, *8*). On the outer side of the rectum, running its entire length, is a band of muscular fibers, the function of which is, probably, to shorten the rectum and to assist in expelling its contents.

The digestive gland (pl. 5, fig. 3, *9*), was formerly regarded as analogous to the liver of vertebrate animals, but the organ contains a diastatic ferment, which converts starchy matters into glucose, and is comparable to the pancreas in vertebrate animals. It contains neither biliary pigments nor biliary acids. The liver of vertebrate animals is not a digestive gland in the true sense of the word, since neither the bile nor an infusion of the hepatic tissues contains a digestive ferment. The name liver could not therefore be appropriately applied to the digestive gland of the Gasteropoda.

The digestive gland is divided into two parts, the larger and inferior of which occupies the outer part of the volution immediately beyond the heart and renal organ. The smaller and superior lobe, in conjunction with the ovotestis, occupies the apical whorls beyond the stomach.

In the digestive gland are innumerable ducts which unite and form a large duct in each lobe of the gland, the three large ducts uniting in one, which, in connection with the duct from the superior lobe of the gland, enters the stomach at a short distance from the beginning of the intestine.

The digestive gland is composed of lobules, which are formed by the enlarged commencements of the ducts, and are lined with

polygonal cells, which become rounded on the removal of pressure[1].

Pedal gland

The pedal gland (pl. 4, fig. 4, 5), is situated in the middle of the basal part of the foot. It is a spongy-appearing mass, extending about two thirds the entire length of the foot, with a central circular passage connecting with the exterior by an opening immediately below the mouth, and sending forth numerous ducts to all parts of the basal portion of the foot. Its office is to secrete the mucus or slime, which the snail so abundantly exudes while moving, and which when hardened by the air presents a glassy appearance.

In the alcoholic extract	enterochlorophyll	
	lecithin	
	oleic acid	
	fatty acids	
	ash	chlorin
		phosphoric acid
		sulfuric acid
In the ethereal extract,	a trace of fat	
In the aqueous extract	sugar	
	globules (coagulating at 66° C.)	
	glycogen	
	sinistrin	
	hypoxanthin	
	ash	potassium
		sodium
		calcium
		magnesium
		iron (traces)
		manganese
		chlorin
		phosphoric acid
		sulfuric acid

Dr Griffith (*Phys. invert.* p. 115) names the following substances as being found in the digestive gland of the Pulmogasteropoda: diastatic ferments, pancreatin, peptones and sodium.

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[1] Dr Levy (*Zeit. biol.* 27: 398) has separated the following substances from the digestive glands of Helix pomatia.

Generative system

Plates 7, 8

The Helicidae and Limacidae are hermaphroditic, and the hermaphroditism is most complete, having complex male and female organs separated from each other, but so arranged that self-impregnation is impossible, the union of two animals being necessary to reproduction.

The generative organs consist of the penis, vas deferens, spermatic duct, oviduct, uterine canal, albumen gland, hermaphroditic duct, consisting of the fallopian tube and spermatic duct, and the ovotestis. On the right side of the foot, about on a line with the beginning of the superior tentacles, is an orifice known as the genital orifice. It presents the appearance of a short slit with the margins in contact, but is capable of great distension. It is from this orifice that the penis is protruded during coition, and into which the penis of the other animal is inserted. Leading from this orifice is a short chamber or tube, known as the cloaca, atrium, or genital vestibule, connecting with the penis and vagina. The orifices of these two organs are situated side by side, that of the penis immediately in front of the vagina.

The penis is a long, cylindric body of a glistening white color, occupying the dorsal anterior part of the foot, nearly straight, very slightly curved. Its walls are strong, thick and composed of muscular fibers. At the base of the penis the walls are very much thickened, and abruptly turned back exteriorly (pl. 8, fig. 1, 2). The inner surface of the walls is plicated (pl. 8, fig. 3). The lining membrane along the bottom of the penis is elevated into a very strong muscular fold (the "pilaster"), nearly filling the interior of the penis (pl. 8, fig. 3). The plications of the inner surface of the walls are surmounted by papillae (pl. 8, fig. 4). The plications of the lining membrane of the penis, and the muscular fold as seen in the penis laid open longitudinally, and in the transverse sections, under a low magnifying power or hand lens present a very beautiful appearance.

The vagina and the spermatheca or receptaculum seminis are

connected with the genital vestibule, the origin of the vagina being immediately posterior to that of the penis. The vaginal body is cylindrically oval in form, having a length of from two and one half to three times the diameter. The walls of the vagina are strong, thick, and consist of muscular fibers. Internally there are a number of strong regular, longitudinal muscular elevations, covered by a double membrane. Near the base these folds are plicated, but become smooth above. At its extremity the vagina narrows into a thin-walled tube or duct, which is of varying length, sometimes short, at other times as long as the vagina. This duct becomes dilated above, forming the receptaculum seminis. The latter organ is elongate oval in form, having very thin walls, and with minute longitudinal folds along the interior (pl. 8, fig. 10, 11, 14). These folds sometimes give a striated appearance to the exterior. The organ is in contact with and closely adhering to the oviduct.

During coition the penis is inserted in the vagina, and is there closely held by the muscular walls and longitudinal folds, the spermatozoa finding their way into the receptaculum seminis, afterward passing down through the vagina, and fertilizing the egg as it leaves the oviduct.

In addition to being a receptacle for the spermatozoa, the receptaculum seminis, according to Dr Leidy[1] "secretes a mucoid matter, which probably facilitates the passage of the ova through the cloaca. The mucus matter in the bladder is frequently found to contain an immense number of an infusorial parasite, which I have described under the name Cryptoicus."[2]

Dr Leidy's description is given at the end of the article on the generative organs.

Ovotestis. The ovotestis, in common with the superior organ of the digestive gland, occupies the apical volutions of the animal (pl. 7, fig. 1, *12*). It is lighter in appearance than the digestive gland, and is composed of a number of bundles or fasciculi of short ceca. Each fasciculus is composed of numerous ceca, is

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[1] Terrestrial moll. and shells of the United States, p. 234.

[2] Jour. acad. nat. sci. new series. v. 1.

broadly pointed at the base, rapidly expanding, circular and convex at the opposite extremity, having very much the appearance of a composite flower. The ceca are sometimes simple, but usually bifurcate or trifurcate. The ceca of each fasiculus connect with a tube, which in turn connects with a duct leading into the hermaphroditic duct. Each cecum seems to have four walls, forming an inner and outer chamber (pl. 7, fig. 7), a tube within a tube. In the outer chamber or tube are produced the ova and in the inner, the spermatozoa.

The hermaphroditic duct leads from the ovotestis to the uterus and penis. It is an extremely convoluted organ, so twisted and confused in P. albolabris as apparently to be composed of short, cylindric, contorted tubes, agglutinated together. In some other species of Helicidae and in Limax it is more nearly straight, being flexuous, sometimes slightly folded or spiral, but not convoluted. This duct is invaginated in the same manner as the ovotestes, the outer tube carrying the ova and the inner the spermatozoa.

Just before reaching the albumen gland the hermaphroditic duct becomes constricted into a delicate thread-like tube. It then enters an accessory gland, which is somewhat the form of a cornucopia, the large end of which is composed of several follicles. The gland rapidly narrows to its opposite extremity. It is partially imbedded in the substance of the albumen gland. Its purpose has not been clearly determined, though from the size and persistency it is undoubtedly important. At the small extremity of the gland the male and female organs become separated, the fallopian tubes passing into the uterine canal, and the epididymis continuing as a spermatic duct on one side of the uterine canal (pl. 7, fig. 1, *9*, and pl. 14, *22*).

Albumen gland. The albumen gland, which is situated at the extremity of the uterine canal, is a large boat-shaped or linguiform gland, of a yellowish color (pl. 7, fig. 1, *14*). The walls of the gland are composed of cells filled with albumen. The interior of the gland is hollowed out by an elongate chamber or duct. The function of the organ is to supply the ova with albumen.

The spermatic duct, as it proceeds along the uterine canal, is invested with a yellowish mass, which has been called the prostate gland. In structure it is composed of very closely packed, simple, tubular follicles, which are lined with pyramidal, epithelial cells, containing at their base a nucleolated nucleus.

At the termination of the uterine canal the male and female organs become entirely separated, forming the vas deferens and the free oviduct (pl. 7, fig. 1, *6*, *7*, and pl. 14, fig. 1, *18*, *19*). The vas deferens becomes enlarged, and for some distance assumes a spiral or twisted form; it then contracts, becoming a long, simple tube, somewhat folded on itself, in order to adapt itself to the restricted space which it occupies. It continues to the extremity of the penis, the walls of which are very thick and muscular. The interior passage or duct is, for the greater part of its length, trilobate in section. As it enters the penis it is somewhat enlarged and the orifice is plicated. It is surrounded by thickened lips and folds, which project into the penis. This fold has a plicated membrane (pl. 8, fig. 6), resembling the membrane of the fold of the penis previously described, and the outer part is nearly in contact with that fold.

The urethra is situated between the lining membrane of the penis and the membrane of the muscular fold (pl. 8, fig. 2).

The retractor muscle of the penis is inserted in the vas deferens at a short distance from the end of the penis (pl. 14, fig. 1, *17*).

Uterine canal. The uterine canal is a large long tube or canal, with plicated or sacculated folds. It is much greater in diameter than the accompanying prostate gland. The walls are mostly composed of polygonal cells, each cell having several nuclei (pl. 7, fig. 1, *8* and pl. 14, fig. 1, *21*). It is within this organ that the eggs are completed.

Oviduct. The oviduct (pl. 7, fig. 1, *7*, pl. 14, fig. 1, *20*) is about the same size as the twisted part of the vas deferens, and continues from the uterine canal to the vagina, entering that organ near its mouth.

During coition the penis is everted, passing out of the genital orifice, and entering the vagina of the second animal, coition continuing for several hours.

The position of the generative organs in the animal can be clearly understood from plate 23, figure 9.

The penis occupies the dorsal anterior part of the foot; the vagina the anterior right lateral part. The receptaculum seminis closely adheres to the prostate gland. The vas deferens is situated between and beneath the penis and vagina; on account of its great length being disposed in irregular folds. The prostate gland and uterine canal enter the first volution of the animal and are disposed alongside the pulmonary cavity. The albumen gland lies between the large lobe of the digestive gland and the stomach. The constricted, thread-like part of the hermaphroditic duct crosses the stomach from the base of the albumen gland, and the convoluted part of the duct lies in the inner margin of the volution, alongside of a part of the stomach. The ovotestis, in conjunction with the superior lobe of the digestive gland, occupies all the apical parts of the animal.

The generative organs of the other species of helicoid snails, though varying in detail, are sufficiently similar to those of P. albolabris to enable the student to recognize them without difficulty, with the exception of those of Gastrodonta intertexta, G. gularis, G. ligera and G. suppressa, which species have accessory organs, that will be described later on.

The vas deferens is usually about twice the length of the penis, or less. In Polygyra exoleta it is longer, but in no species, as far as I am aware, is it as long as in P. albolabris. In P. tridentata and in P. exoleta it has the same form as in P. albolabris, that is, enlarged, glandular, annulated or somewhat spiral in appearance at its beginning; while, on the contrary, in Pyramidula solitaria it has this form at its termination. In Omphalina fuliginosa it is for a great part of its length expanded, so that its diameter is equal to that of the penis.

In some species, as in Polygyra auriculata and P. sayi, the penis is very long and bent on itself, while in others, as Pyramidula solitaria, it is short, stout and clavate.

In Polygyra profunda the base of the penis is included in a sheath formed by a continuation of a part of the genital chamber, in the form of an inverted cone. In Circinaria concava it is long and cleft or bipartite at the summit.

The lining membrane usually has a number of rugae, longitudinal and oblique. Sometimes, as in P. albolabris and Pyramidula alternata, there is one very large fold. In many species, as in P. albolabris, the surface of the membrane is papillated, but in some others it is smooth.

The vagina and receptaculum seminis vary in form. In the greater number of species the vagina is not as large and muscular as in P. albolabris, and the duct leading to the receptaculum seminis is generally longer.

In Helix aspera and other European species there are several accessory organs not found in P. albolabris or in Limax. They are the flagellum, the dart sac and the accessory mucous or digitate glands.

The flagellum is an elongated diverticulum of the penis and is much coiled. The dart sac is an elongated, clavate, appendage from the base of the oviduct. It has powerful muscular walls, and contains in its interior the dart or spiculum amoris, attached to a nipple-like protuberance at the bottom of the sac. The dart is four-bladed, calcareous, and growing by the addition of calcareous particles, deposited at its base from the vascular protuberance to which it is affixed. If broken off it is speedily renewed in like manner. Before coition the dart sac is everted from the genital orifice, the dart thus becoming exposed. It is probably an excitatory organ.

The mucous or digitate glands, according to T. Rymer Jones, "consist of a series of branched ceca, derived from two excretory ducts, by which a milky fluid, secreted by the ceca, is poured into the egg passage prior to its termination".

The receptaculum seminis of Helix aspera differs greatly from that of P. albolabris and Limax maximus, consisting of an elongated duct, which subdivides into two

cecal diverticula, a longer and stouter coiled one, and a shorter one with globular head, which during life is concealed in the first coil of the intestine.

It is a remarkable fact that, while the flagellate form of the penis, and the accessory organs, viz, the dart sac and multifid vesicles, are very common in European species of Helix, they are very rare in east American forms. A flagellate form of the penis does not exist in a single one of the latter forms. An analogue of the multifid vesicles exists in only four of the species occurring in New York. In Gastrodonta intertexta and G. gularis there is a single pair of follicles. In G. ligera and G. suppressa there is but one short follicle. The dart sac exists in the above-named species.

Description of a new species of entozoa

BY DR JOSEPH LEIDY

Plate 13, fig. 6

In September 1846 I first gave an account in our proceedings of a new genus and new species of Entozoa, inhabiting the fluid contained in the spermatheca of Helix albolabris, H. tridentalis and H. alternata. Since then I have verified the observation, and also have detected it in other species of Helix, viz, elevata and thyroides, and have also detected it in an allied genus, Bulimus decollatus. The name which I gave it at that time I was not aware had been previously applied to a genus of Insecta brachelytra, with the only difference of the latter having a neuter termination. I will therefore change the name.

Cryptoicus minutissimus; forma mutabilissima; organisatione interno cellularium et granulosum, C. helicis. Coloris expers; forma plerumque elongata, fusiforme, vel ovata; caudis duabus adversis, una longior quam altera. Structura interno stomachos duos et granulos numerosus parvos exhibit. Long $\frac{1}{125}-\frac{1}{100}$ lin. Habitat in spermatheca Helices albolabris, tridentata et Bulimus decollatus.

This singular entozoon is a polygastric animalcule. Its varied forms and movements are curious to observe; at one moment globulose, then oval, ovate, fusiform, sigmoid, crescentic, etc. It appears as if it would outvie the kaleidoscope in its changes. Sometimes it collects in bunches, adhering by the end of the cauda to each other, and frequently it may be observed to contract upon either of the large cellules, causing them to project beyond

the outline of the animal. The motions are vibratile rotary, with a lateral progression, or whirling in circles like the insect Gyrinus. Cryptoicus from its position might be mistaken for the spermatozoa of the animal, but may be readily distinguished; the spermatozoa of Helices having either a uniform sigmoid or a spiral body, with an enormous proportionate length of tail, and a slow vibratile motion.

Plate 13, figure 6, represents some of the varied forms of the animal highly magnified.

Circulatory system

Method of injecting the blood vessels. I have found the following method to be the best in obtaining a complete injection of the circulatory system, and by it I have obtained the most beautiful results, plainly showing all the minute ramifications of the arteries and veins.

The necessary materials are an ordinary hypodermic syringe, with as fine a needle as it is possible to obtain, the finer the better; as an injection which would not pass through the finest hypodermic needle certainly would not pass through the fine arteries and veins. The distal extremity of this needle should be blunt or slightly bulbous. A curved sewing-needle and very fine thread are also necessary. As an injection fluid I have used and found perfectly satisfactory Dr Seiler's carmine gelatin. This is sold by the ounce and comes in a solid mass.

A day or two before making the injection, some of the gelatin should be placed in cold water in a wide-mouthed bottle. The water will soften the gelatin. When it is proposed to use the injection, the bottle can be set in a pan of hot water. Within a short time the gelatin will be completely dissolved. It should be thin enough when hot to enter easily the arteries and veins, but of sufficient consistency to harden when cold. No rule can be given as to the exact proportion of water and gelatin. The right degree of fluidity must be determined by each student. Use only filtered water with the gelatin, as a small particle of dirt in the water might prevent a successful result.

Take the animal as soon after death as possible; wash away the mucus. Then, as previously described, remove the shell,

wholly or till the heart can be plainly seen. The latter method is, I think, preferable, as it avoids the danger of rupturing some of the blood vessels, as sometimes happens when the entire shell is removed. Cut through the peritoneum, alongside the rectum, taking care not to injure the large vein which accompanies the rectum; turn back the walls of the pulmonary cavity till the heart is exposed. Using the curved needle pass a thread under the ventricle. Place the animal in warm water, as hot as can be comfortably borne by the hand, and before injecting be certain that the animal is thoroughly warmed through; also place the syringe in hot water, having both the syringe and injecting fluid warm. Draw some of the fluid into the syringe; then, holding the needle upward, expel a drop or two of the fluid, so as to be certain that no air remains in the syringe. Leaving the animal in warm water, with the point of an extremely sharp scalpel make a slight incision in the walls of the ventricle just large enough for the point of the needle to enter. Insert the needle, bring the two ends of the thread together and tie them just back of the point of the needle, to guard against the escape of the injection through the incision. Some assistance would be useful in this operation, as one hand will be occupied with the syringe. Gently press the piston, slowly injecting the fluid, stopping immediately when the injection is complete, as much pressure will rupture the walls of the blood vessels.

Sometimes a very fine injection of the arteries can be made by merely inserting the point of a hypodermic needle in the ventricle, the rest of the process being as described above. But the injection is liable to escape where the needle enters the wall of the ventricle.

The injecting is a very delicate process, and partial, or even a complete failure at the first attempt should not discourage the student. The most frequent cause of failure is in not keeping the animal and syringe warm enough, the injecting fluid rapidly hardening in the blood vessels, preventing their full injection.

When the animal is fully injected, place it at once in cold water; this rapidly hardens the gelatin. The remainder of the

shell can now be removed and the animal immediately dissected, or it can be placed in alcohol for future use. The alcohol must be at first very weak, gradually increasing its strength each day.

The advantage of a gelatin injection over a fluid one is that, as the gelatin becomes hardened, dissections can be made without danger of the escape of the injection from the severed blood vessels. As the injection is a brilliant carmine, the blood vessels stand out in bold relief from the light background of the various organs.

Heart. The heart (pl. 9, *1*, pl. 10, fig. 1, pl. 14, fig. 1, *30*, *32*) is situated in the outer portion of the first volution, just anterior to the peristome, and is plainly visible from the exterior. Its pulsations can be observed even through the shell. Ordinarily the pulsations number about 45 or 50 a minute, in an adult individual; but are variable, sometimes being much faster, and during hibernation slower. In a young individual the pulsations seem to be much faster, sometimes equaling 150 a minute. The heart consists of a single auricle and ventricle, inclosed in an oval pericardiac sac. The ventricle and auricle are pyriform, placed base to base, the bases being somewhat truncated. The ventricle is about twice the size of the auricle.

In composition the walls consist of unstriped muscular fibers, granulated, showing oval nuclei on the application of acetic acid.

The interior of the heart is lined with tesselated epithelium, consisting of granulated cells. The interior of the walls of the aorta have a similar structure.

The wall of the pericardium is very thin and transparent. The pericardial fluid is very abundant, and, according to Dr Leidy, is sometimes inhabited by an entozoon, named by him Distoma vagans.[1] Between the auricle and ventricle is a valve, so disposed as to permit the passage of the blood only from the auricle to the ventricle.

Arteries (pl. 9, fig. 1). The apex of the ventricle gives origin to one large aorta, which almost immediately subdivides, one branch proceeding posteriorly, and supplying the digestive gland,

[1] Jour. acad. nat. sci. new series. v. i Philadelphia.

hermaphroditic duct, stomach, ovotestis and albumen gland; the other and larger of the two proceeds anteriorly, supplying the remaining organs of generation, muscles, crop and all the organs contained in the foot.

The posterior aorta passes on the outer part of the inferior lobe of the digestive gland, giving off numerous branches to this gland, the intestine and also to the albumen gland. Just after giving off this latter branch, it crosses a portion of the stomach, and for a short distance disappears in the substance of the lobe of the digestive gland; then emerging it continues along the lower inside edge of the volution to the apex of the animal, giving off branches to the superior lobe of the digestive gland, and to each of the fasciculi of ceca composing the ovotestis.

The anterior aorta, at a short distance from the heart, gives off a branch to the stomach. On the stomach this branch subdivides into two branches; each of which gives off numerous branches, covering the stomach with their ramifications. This artery, before reaching the stomach, gives off a branch, which continues to the hermaphroditic duct.

At a short distance from the branch to the stomach is a large branch, which continues on the surface of the prostate gland and uterine canal, giving off numerous small branches to these organs.

At a short distance beyond this branch is another, which shortly subdivides; the larger of the two divisions continuing to the muscular collar, and supplying blood to it, and to the adjacent parts. The smaller of the two divisions continues with the retractor muscles of the foot. From the larger of the two subdivisions a branch is given off, which continues to the crop, supplying the crop and the overlying salivary glands. A small branch continues with each salivary duct to the buccal body.

The main aorta continues, without branching, to the infraesophageal ganglia, where it suddenly turns downward and backward, continuing posteriorly in the base of the foot. Just at the turn it gives off three branches, which proceed directly anteriorly; the central and largest of which supplies the buccal body. The two lateral ones, which are very minute, proceed

to the cephalic integument. A branch is also given off, which proceeds alongside the nerve to the muscular collar. Branches also accompany the commissural cord, forming a complete circle. From this, on the left side, arteries proceed to the tentacles; from the right side an artery proceeds, which subdivides; one branch proceeding to the penis, the other to the vagina; these organs being covered by numerous ramifications. From the artery near the ganglia proceed the arteries supplying the tentacles of the right side.

Veins. The arteries break up into smaller and smaller branches, and finally into a network of capillaries, that meet a similar network leading to the veins, which empty into large veins or sinuses; the principal ones of which are three in number. The first begins in the apex of the volutions, receiving the veins from the superior lobe of the digestive gland, continuing on the outer edge of the volution to the beginning of the pulmonary chamber, receiving in its course several large veins. These divide, one division passing along the edge of the pulmonary chamber, alongside the rectum to the thickened muscular collar, passing along the inner edge of this to the base of the pulmonary chamber. The other division passes along the base of the pulmonary chamber, uniting with the first described division at the muscular collar, forming a sinus completely incircling the pulmonary chamber, and known as the circulus venosus pulmonis, or pulmonary circulus.

The arteries of the foot, as in the visceral part of the body, break up into capillaries, that enter the capillaries of the veins, which empty into a large vein or sinus, situated below the pedal gland. From this sinus proceed numerous veins, which finally connect with the pulmonary circulus.

From the pulmonary circulus arise many veins, which form a large vein leading to the heart, and known as the pulmonary vein. These veins are known as the efferent veins. They alternate with much regularity with a series of veins leading from the pulmonary vein, but intimately connected with the efferent vessels, which are known as the afferent veins (pl. 11, fig. 1-4).

Circulation. The circulation is as follows: the blood leaves

the heart by the aorta, and is distributed by the arteries to the different parts of the body, and passes from the minute branches of the arteries into a flexus of capillaries spreading over the whole body; passing from them into the veins, and from the veins into the sinuses previously described; finally all the blood entering the pulmonary circulus; and thence the pulmonary veins, where, circulating freely through efferent and afferent vessels, it becomes thoroughly aerated.

The renal organ or kidney is supplied with blood, which has previously been aerated, but only a small part of the blood passes each time through it.

Though the veins are situated in the substance of the body, and their walls are much thinner than those of the arteries, they are not simply lacunae or wall-less passages in the body, as they have frequently been described. The walls though thin are distinct.

Blood. In animals of the simplest structure all the fluids seem to be of the same nature and seem to be " only water charged with organic particles, but in animals higher in the scale of being the fluids cease to be of the same nature, and there is one, distinct from all others, destined to nourish the body. This fluid is the blood. It not only nourishes the body, but is the source from whence is derived all the other secretions, such as saliva, urine, bile, etc."

In the higher animals the blood is of a red color; but in the Invertebrata it is of different densities and of various colors.

The blood of the Helix and Limax consists of a nearly transparent fluid in which float solid corpuscles.

For the following facts in regard to the composition of the blood I am indebted to Dr Griffith's *Physiology of the Invertebrata.*

In the majority of the Invertebrata the carrier of oxygen to the tissues is haemocyanin, contained in the blood, but in many of the Annelida, as well as in nearly all of the vertebrates, the transport of oxygen from the surrounding medium (air or water), to the living tissues is made by the hemoglobin of the blood. This substance, as is well known, forms an oxygenized condition which is very unstable, and which is carried by the blood across the tissues of the animal, and is there dissolved, yielding its oxygen to those tissues which require it.

In Gasteropoda, as well as in Cephalopoda, Crustacea and Arachnida the function of respiration is brought about by an albuminoid substance analogous to hemoglobin, but containing copper instead of iron, this substance, which Fredericq names haemocyanin, forming a very unstable combination.

The saline matter contained in the blood of the Helix is about 1.075%; in Limax about 1.115%.

Touching the color of the blood, Mac Munn[1] says in regard to the blood of Helix pomatia: "It assumes a distinct blue tint on exposure to the air, and gave no absorption bands, but absorbed a little of the violet end of the spectrum. On treatment with ammonia its color was not so well marked, and it had a partially reddish tinge, but no bands could be seen, and after, treatment with acetic acid did not remove the color."

One time I drowned 12 individuals of P. albolabris, leaving them, as usual, in the water about 48 hours. The blood in the arteries of all these specimens had coagulated and turned a dark purple black in color, so that the course of the arteries could be as distinctly traced as if they had been injected. I am unable to account for this phenomenon, as of scores of specimens, treated in the same manner, these were the only specimens coagulated and colored, though the others were kept in the same box and fed on the same kind of food.

Nervous system

The nervous system (pl. 12) consists of five distinct sets of ganglia, and four ganglionic swellings, and the commissures connecting them or proceeding from them. The principal ganglia are the supra-esophageal, the infra-esophageal, consisting of two sets, and the two buccal ganglia. The ganglionic swellings, or ganglia, are situated at the extremity of the tentacles. The ganglia corresponding to the one situated on the dorsal surface of the stomach in Limax maximus I have not observed in Polygyra.

When the animal is extended, the supra-esophageal ganglia are situated just above the esophagus, immediately posterior to

[1] Quart. jour. micro. sci. 1885

the buccal body, but varying somewhat in position according to the degree of contraction of the body.

The infra-esophageal ganglia are situated below and just posterior to the buccal body, and are connected with the supra-esophageal ganglia by a double commissure. The buccal ganglia consist of two small masses, situated just below the surface of the posterior dorsal part of the buccal body. They are connected with each other and with the supra-esophageal ganglia.

The esophageal ganglia and the connecting commissures are enveloped by an essentially opaque sheath, and it requires very careful manipulation to remove this so as to determine the form of the ganglia. This is best effected by two small needles fixed in the end of small round sticks, as described on page 241, using one in each hand. The points of the needles should be inserted just below the surface of the sheath, and a little of it torn away with each insertion, being very careful not to introduce the needle far enough to penetrate the ganglia beneath. The fine forceps, mentioned on page 241, will be found useful in removing the loosened parts of the sheath. In this operation it is necessary to proceed very slowly. Any undue haste will almost certainly result in the destruction of the ganglia.

The supra-esophageal ganglionic mass, before the removal of the sheath, has the appearance of a single quadrangular mass, wider than long, the posterior margin incurved. The double commissures proceeding from the posterolateral extremities, appear as single large, flattened nerves. When the sheath is removed, the supra-esophageal ganglionic mass is seen to be composed of two sets of ganglia, connected by a commissural cord, the ganglia of each set being aggregated together, the two ganglionic masses being precisely similar in detail. The principal one of the supra-esophageal ganglia (pl. 12, *a*) is subquadrangular or subovate in outline, about two and one half times as long as wide, slightly constricted at the middle. Attached to the lower outer part of this ganglion is a smaller ganglion, about one fourth the size of the preceding one. Attached to the posterior part of these ganglia are three comparatively small, nearly round ganglia (pl.

12, *a*), so aggregated as to have, on a superficial examination, the appearance of an oblong mass.

The infra-esophageal ganglia have, before the removal of the sheath, the appearance of a flattened, circular mass, with a central opening through which passes a large artery. When the sheath is removed, it is seen that the ganglia form two masses aggregated together, making a sub-circular mass. The upper mass is composed of five subovate ganglia, of nearly equal size (pl. 12, *b*). One is situated dorsally and centrally, and two on each side of this one. The lower part consists of two larger ovate ganglia, joined to each other and to the ganglia above them.

The buccal ganglia are small, somewhat kidney-shaped bodies (pl. 12, *n*).

The ganglia of the superior tentacles are subpalmate in form, the palm being unduly developed, and the fingers very short (pl. 12, *e*).

The ganglia of the inferior tentacles are pear-shaped (pl. 12, *i*).

The commissures connecting the supra and infra-esophageal ganglia are of equal size. The upper commissures proceed from the posterior part of the outer supra-esophageal ganglia, and are connected with the anterior part of the lower ganglia of the upper part of the infra-esophageal ganglionic mass (pl. 12, *c*). The lower commissures proceed from the outer ones of the small, nearly round ganglia of the supra-esophageal ganglionic mass, and are connected with the lowest two ganglia of the infra-esophageal ganglionic mass, or, as they are sometimes designated, the pedal ganglia (pl. 12, *c*).

From the inner anterior part of the principal supra-esophageal, or cerebral ganglia, proceeds a large, conspicuous nerve, which connects with the ganglia at the extremity of the superior or ocular tentacles (pl. 12, *d*, *e*). This nerve, after entering the tentacle, gives off a nerve which proceeds to the eye, the optic nerve (pl. 12, *f*, *g*); also from the outer anterior part of each ganglia a nerve proceeds to the mouth and adjacent integument.

From the central anterior part proceed two very delicate nerves which continue to the integument of the superior tentacles.

From the lateral ganglia of each mass proceed two very conspicuous nerves; the inner one (pl. 12, *l*), continuing to the mouth, the outer one continues anteriorly, branching; one branch (*k*) going to the mouth and adjacent parts, the other (*i*), continuing to the ganglion at the extremity of the inferior tentacles.

The nerves previously described give off branches to the anterior part of the body, also to the penis and vagina.

From the lower inferior part of the principal ganglion proceeds a commissural cord (*o*), connecting with the buccal ganglion.

The anterior extremities of the buccal ganglia are connected by a commissural cord.

From the buccal ganglia nerves pass off: first, two nerves, anteriorly, to the surface structure of the buccal body; second, two branches, which penetrate posteriorly into the buccal body; third, a branch accompanying the salivary duct to the salivary gland; fourth, a branch to the esophagus; fifth, a nerve to the anterior part of the buccal body.

From the infra-esophageal ganglionic mass proceed the following described nerves: from the dorsal ganglion a very conspicuous nerve (*p*), which takes the same general direction as the cephalic artery, continuing alongside the uterine canal. At the point where the arteries give off branches to the muscles and the crop the nerve passes through the loop thus formed, and also gives off branches both to the muscle and to the crop. It then continues, slightly diminished in size, along the uterine canal to the albumen gland. The main part continues along the albumen gland; a branch accompanies the hermaphroditic duct to the ovotestis, giving off filaments to the stomach and digestive gland. Another branch proceeds to the heart and renal organ. From this branch a smaller branch proceeds to the adjacent parts of the digestive gland. The nerve is easily traced to the digestive gland, but from that point the nerves are very fine, and careful study is necessary to distinguish them.

From each of the two ganglia adjacent to the dorsal one, a very large nerve passes to the muscular collar (*r*); bifurcating just be-

fore entering the collar, one branch passes through the muscles, the other continuing in the pulmonary chamber.

From the inferior part of the lateral ganglia proceed five nerves on each side (*u*), continuing to the integument.

From the pedal ganglia proceed two large nerves, running nearly directly backward and parallel to the central part of the base of the foot, giving off several branches. From the pedal ganglia there are about 12 other nerves, supplying the base of the foot.

The ganglia are composed of cells or globules, varying very much in size, round or polygonal from mutual pressure, having a nucleus which occupies one half or two thirds the globule. The nucleus has several transparent nuclei. The nerves consist of bundles of tubuli. The walls of the tubuli are transparent.

Special organs of sense

Touch. The sense of touch is extremely acute in every part of the foot; the integument and base of foot being liberally supplied with nerves. The tentacles are specially sensitive, but I have not been able to touch any part of the foot so lightly that it was not immediately felt by the animal. In motion the animal depends more on the sense of touch than on eyesight.

Taste. There is no doubt that the animal possesses some sense of taste, but, from long observation, I think that in the selection of food the animal depends more on the sense of smell than that of taste.

Light. The eyes of both Helix and Limax are situated at the extremity of the superior tentacles, and are conspicuous, having the appearance of bright, black specks. Under a low power can be seen the globular eyeball invested by a transparent tunic, corresponding to the cornea; the crystalline lens lying under the delicate cornea; the choroid, which forms two thirds of a sphere, transparent and having a single layer of irregularly round or oval, black pigment cells. Polygyra is nocturnal in its habits, and perhaps at that time it can see more clearly; but in all my experiments with different individuals, many of them conducted with only sufficient light to distinguish the animal, I have seen no evi-

dence that Polygyra is possessed of sight, with the single exception that young individuals placed on a table, by a window, seemed to crawl away from the light, but in adult individuals the light did not seem to make any difference. I have very frequently moved a stick or some bright object directly in front of the extended tentacles, as the animal was moving, but with no effect whatever. Often I have observed the animal running directly into an object, withdrawing its tentacles and changing its course only when the tentacles touched the object.

Smell. That the snail possesses olfactory organs admits no dispute, but the location of these organs has been a matter of doubt. I have had many snails in captivity for three years, and I have frequently experimented with them to determine what degree of olfactory sense they possess. After leaving them without food for several days, I have put in one corner of the box a small head of lettuce, concealing it by a few of the dead leaves. In a short time the snails would appear from under the leaves, and on the surface would raise the anterior portion of their bodies in the air, with extended tentacles, turning from one side to the other, having exactly the appearance of a quadruped sniffing the air in the endeavor to locate some object. Having decided on the position of the lettuce, they would invariably move directly toward it, and this sometimes from a distance of 18 inches. I have repeated this experiment again and again but always with the same result. It was impossible for the animals to see the lettuce on account of the screen of leaves, and, as previously asserted, I am satisfied that their power of vision is extremely limited, at least by daylight or by artificial light.

The discrimination in regard to food must be due also in a great degree to the sense of smell. I have placed in my box of snails young beet leaves, spinach and other tender vegetables, which it would naturally be supposed would be acceptable to the snails; but they invariably refused to eat them, though deprived of other food, and in no case were these articles even tasted, showing, I think, that they were rejected on account of their odor.

It being admitted that they possess olfactory organs, it remains

to locate them. Dr Leidy[1] and Dr Sochaczewer,[2] believed that the olfactory organs are situated in the pedal sinus.

The latter author made the following experiment:

Having cut off the tentacles of Helix pomatia, the wound was allowed to heal. The snails were then placed on a flat plate, the edge of which was smeared with turpentine; both the mutilated and unmutilated specimens turned away from the edges; this shows that the tentaculae are not the seat of the olfactory organs.

I do not think that this experiment is at all conclusive, or in fact has any bearing on the matter, as the foot both of Helix and of Limax is so extremely sensitive that on the first contact with any substance smeared with turpentine the animal would turn quickly away; the effect being essentially the same as if the animal had come in contact with heated metal. The fatal defect of this experiment is that the sensitiveness of the foot was not taken into consideration. I have tried the same experiment as far as surrounding the animals with turpentine, but they never turned away till they came in contact with the turpentine. If they turned away on account of the smell, they would do so before touching the turpentine.

If one observes a snail, when in motion, it will be seen that the superior tentacles are usually held, essentially, in one position, occasionally striking an object, apparently not seeing it; but the inferior tentacles are constantly in motion, and are bent down toward the object on which the animal is moving, but not touching it. Taking into consideration the limited power of sight, it seems to me that the snail must be assisted by the sense of smell.

That these tentacles have an important function to serve is evident from their anatomic character. A large nerve proceeds from the principal of the cerebral or supra-esophageal ganglia, which connects at the extremity of the tentacle with a very conspicuous ganglionic swelling (pl. 13, fig. 4, 5), which gives off numerous nerve fibers to the extremity of the tentacle. That the tentacles are not tactile organs is evident from two facts; first, they would

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[1]Terrestrial moll. and shells of the United States.

[2]Zeitschrift für Wiss. zoologie. 35:133.

be unnecessary, as the foot is well supplied with nerves, and is very sensitive; second, though the tentacles are bent down toward the object on which the animal is moving, I have never seen them touch the object. Furthermore, the tentacular ganglia are anterior to all others, with the single exception of the ganglia of the superior tentacles, and are attached by their nerves to the cerebral ganglia, which, taken in connection with the anterior position of the tentacles themselves, corresponds to the position of the olfactory organs in vertebrates. When the tentacle is withdrawn, the olfactory sense still exists; the olfactory organ then closely corresponds to the olfactory organ of fishes. Negatively, the olfactory organ certainly does exist; but the nerves at the mouth, which have been considered by some authors as olfactory nerves, are undoubtedly nerves of taste; while the pedal sinus is clearly for the secretion of mucus, which the animal so abundantly exudes while in motion. Taking into consideration the anatomic details of the inferior tentacles, and innumerable observations of the use of these organs by the animal, I have no hesitation in affirming that they are olfactory organs.

In some forms of Gasteropoda no tentacles exist, and it will be interesting to determine whether in the absence of tentacles the olfactory sense is deficient. In relation to this Albany Hancock,[1] says:

> Being engaged at present in the investigation of the anatomy of some members of this family, my attention was naturally directed to this point, and I think that I have obtained satisfactory proof that these hornless animals have really the sense of smell highly developed. The head lobe in the Bullidae is, in fact, nothing else than the dorsal (superior) and labial (inferior) tentacles fused in one continuous mass. This Cuvier asserted long ago; and it can be very easily proved on anatomical grounds . . . It may therefore suffice to say at this moment, that the nerves which supply the oral (inferior) and dorsal (superior) tentacles in the Gasteropoda go to this lobe, the former to the anterior and the latter to the posterior portion of it; a pretty clear proof of its real nature.

Hearing. The so-called auditory organs consist of two trans-

[1] Ann. and mag. nat. hist. 1852.

parent vesicles, situated beneath the sheath of the supra-esophageal ganglia, one on each side, placed immediately on the ganglia and connected with nerves proceeding from the cerebral ganglia. They are extremely minute, and are filled with a transparent fluid, containing a number of small bodies, composed of concentric layers of carbonate of lime, frequently hollow at the center, called otoliths. During life, and for a short time subsequent, these bodies have a peculiar vibratory motion.

The size and situation of these bodies, and their nerves, would naturally lead to the conclusion that as auditory organs they would be of little, if any, use. As with Anodonta, I have tried numerous experiments to test the sense of hearing. Any noise which does not jar the animal, has no effect on it. And I have no hesitation in saying that the sense of hearing, if ever possessed, has been lost.

These remarks apply both to Polygyra and to Limax.

Sense of direction. Snails in common with most animals, with the exception of man, have what has been called the sixth sense; that of direction or locality. I had for several months a large box, containing about one hundred snails, in one corner of my library. At the time I was making sections of shells to illustrate this work. I one day examined the snails in the box, and picked out three which were to all appearances dead. These I took out for the purpose of making sections of the shell. Not having time then, I laid them on the window ledge, in the opposite corner of the room, about 12 feet from the box. Several hours later I looked for them, and, not finding them, thought they had been accidentally brushed from the ledge. Looking on the floor for them, I noticed the peculiar, glass-like trail made by a snail while moving. Then, examining carefully the spot where I had laid them, I found that, though apparently dead, they were alive, and I easily traced the three snails by their trails, which led in an absolutely straight direction to the box in which they had been kept, and I found them under the edge of the mosquito netting, which had been tied over the box, as near to the interior of the box as it was possible for them to reach. Afterward I experi-

mented several times by placing individuals in various parts of the room, and once in another room. They almost invariably returned to the box.

LIMAX MAXIMUS *L.*

The animal has a thick vermiform body, with a broad, ribbon-like pedal disk, having very much the appearance of the so-called foot of the Polygyra. The mouth, tentacles, etc., are situated as in that genus. The anterior part of the body is rounded. The posterior is acute and dorsally keeled.

The mantle is situated on the anterior dorsal part of the body, and is somewhat shield-shaped. The anterior margin is rounded; the posterior margin angular. It consists of a thick, fleshy membrane. The anterior part is free from the body, and, when the animal contracts, the head is concealed beneath it, the mantle coming down before the head like a mask. The posterior part is not movable. It contains the rudimentary shell, and covers the pulmonary chamber, heart and renal organ.

The respiratory orifice is situated on the right side of the mantle, about midway of its length; the mantle being notched or curved around the orifice.

The genital orifice is situated anteriorly on the right side as in Polygyra.

The body is divided into two cavities; the smaller containing the pulmonary chamber, the heart, renal organ, and a part of the rectum, the larger containing the digestive and reproductive organs, the nerve ganglia and the principal muscles.

Limax differs from Polygyra in that all the organs are contained in the vermiform body, corresponding to the foot of Polygyra, and in being possessed of only a flat, rudimentary shell. Polygyra resembles a Limax "with the greater portion of the mass squeezed out on the back, and arranged in a turbinate manner", and covered by a shell.

The integument consists of a thick mucous membrane, with a muscular substratum, as in the foot of Polygyra. It is nearly uniformly developed, but is thickest on the mantle, tail and pedal

disk. On the head and upper part of the body, anterior to the tentacles, it is very thin.

The mantle and body have black markings, which vary in intensity on different individuals.

Digestive system

Plates 15, 16

The esophagus is very short, and has a diameter of about .6 mm. It leads into the crop, somewhat abruptly expanding to a width of about 4 mm and continues essentially in a straight line for nearly three fourths the length of the body, slightly diminishing in diameter. It then contracts, quickly expanding to nearly its former diameter, to form the stomach, continuing for about one fifth the length of the previous part, gradually diminishing in size, then turning abruptly forward and ending in a position nearly parallel to the constricted part.

The intestine leaves the posterior part of the stomach, and proceeds anteriorly through the digestive gland, where it turns to the left, and, making a broad curve in the gland, again proceeds anteriorly, in contact with the previously described portion for a part of the distance; then, turning to the right, it forms a loop over the retractor muscles, near their origin; again proceeding posteriorly on the dorsal surface of the crop, nearly to the constrictor of that organ; again abruptly bending forward and continuing in contact with the last described part, passing under the pulmonary chamber, terminating at the anal aperture near the respiratory orifice.

The latter two convolutions are oblique to the crop and lie on its dorsal part. In nearly all the specimens which I have examined they are empty and flat, even when all the other parts of the intestine are filled with the remains of food. They are very unlike the rest of the intestine in appearance. Their abrupt turning backward and simultaneous decrease in size, and their dissimilarity in appearance to the rest of the intestine are very misleading, and it requires careful dissection to show the continuity with the rest of the intestine, as they greatly resemble a cecum.

Salivary glands. The salivary glands are situated on the anterior part of the crop, the one dorsally and the other latero-ventrally. They vary in shape and size (pl. 23, fig. 5, 6) the dorsally situated one being the smaller. They consist of numerous lobuli, which are conglomerate. From each gland proceeds a conspicuous duct, which enters the buccal body, one on each side of the esophagus.

Digestive gland. The digestive gland consists of three principal lobes, divided into lobules. It, in conjunction with the ovotestis, occupies the posterior part of the animal, and also invests the greater part of the stomach, and the posterior lateral part of the crop. See plate 15, figure 3, for its position, and plate 23, figures 7 and 8, for its form.

Generative system

Plates 15, 17

The general appearance of the generative organs is the same as in Polygyra, varying only in details, with the exception of the ovotestis.

The penis and anterior part of the other organs pass obliquely over the anterior part of the crop (pl. 15, fig. 2), a part of the uterine canal and spermatic duct lying ventrally and to the left of the crop. The ovotestis is situated at the posterior end of the animal, on the dorsal part of the digestive gland.

The penis is a long, cylindric body, comparatively much longer than in Polygyra albolabris. The posterior end is curved and bent on itself. It is destitute of the outer fold or so-called prepuce existing in P. albolabris.

The retractor muscle of the penis is long and inserted, together with the vas deferens, on one side slightly anterior to the extremity.

When exserted, a thin, erect membrane is shown extending backward from the meatus; and also membranous folds at the meatus.

The vagina and receptaculum seminis are much smaller than in P. albolabris.

The vas deferens is short, its length being equal to or less than

that of the penis. For about one half of its length it is thickened, annulated and glandular, becoming cylindric and filiform, entering the penis on the side, just anterior to the extremity.

The uterine canal is conspicuous, but does not present so distinctly a sacculated appearance as in P. a l b o l a b r i s.

The albumen gland is large, flattened, rounded at each extremity, broadest at the anterior, gradually diminishing to the posterior.

The hermaphroditic duct is short, flexuous, but not convoluted, as in P. a l b o l a b r i s.

The ovotestis consists of an oval, flattened mass, formed by an aggregation of ceca. It is nearly four times as long as wide; situated on the dorsal part of the posterior end of the digestive gland. It differs greatly from the ovotestis of P o l y g y r a.

Circulatory system

Plates 18, 19

Heart. The heart is situated at the lower left side of the pulmonary chamber. It consists of a single auricle and ventricle, each pyriform, placed base to base, the bases being truncated. The auricle is anterior to the ventricle and about one half its size.

Arteries. The aorta (pl. 18, fig. 1) proceeds from the apex of the ventricle, and almost immediately divides into two principal branches, the anterior and posterior of about equal diameter. The aorta divides before leaving the pulmonary chamber, giving the appearance of two aortae proceeding from the heart.

The anterior artery proceeds for a short distance laterally, then anteriorly. It supplies the stomach, salivary glands, penis, receptaculum seminis, buccal body and nerve ganglia. At the ganglionic mass it turns abruptly backward, and proceeds along the middle of the ventral part of the animal, immediately above the pedal sinus; continuing for about one half the length of the animal, then bifurcating and entering the foot.

Where the artery bends forward a large branch is given off to the crop. This branch almost immediately subdivides, the principal branch proceeding anteriorly on the dorsal part of the crop.

Near the esophagus it bifurcates, a branch proceeding to each of the salivary glands, and anterior part of the crop. In its progress to the anterior part of the crop it gives off four branches, two on each side of the crop. These branches in turn give rise to numerous others.

The second principal branch (*3′*), proceeds posteriorly for some distance, giving off comparatively few branches.

At the subdivision of the anterior and posterior crop arteries there are two smaller branches (*4*, *3″*), the first of which proceeds to the uterine canal, the second directly to the ventral part of the crop, giving off several branches principally posteriorly.

At the ganglionic mass, where the aorta turns downward and backward, a branch continues forward under the buccal body (*13*), giving off small branches to the buccal body, muscles, lips, etc. Branches from the anterior artery accompany the commissural cords connecting the two principal ganglionic masses, forming a complete circle, as in P. albolabris (*14*), giving off branches to the tentacles (*15*).

Just previous to its turning backward the anterior artery puts out a branch, which subdivides and supplies the penis and vagina (*11*, *12*).

The posterior aorta gives off branches to the stomach, intestine, digestive gland, uterine canal, hermaphroditic duct, ovotestis, etc. The first branch follows the course of the intestine, entering a lobe of the digestive gland, and ramifying through it. Very near this the artery gives off a branch, which proceeds along the hermaphroditic duct to the ovotestis. Two small branches have previously been given off to the hermaphroditic duct. Several small branches are now given off to the intestines at frequent intervals.

From the opposite side of the artery a branch proceeds to the upper attenuated end of the principal lobe of the digestive gland, giving off numerous branches throughout the lobe.

The next branch continues along the outer surface of the large lobe of the digestive gland, giving off numerous branchlets, which ramify throughout the lobe.

Immediately after the anterior artery bends abruptly toward the

anterior portion of the animal, the large artery, which supplies the stomach, gives origin to a comparatively large branch to the digestive gland, and gives off numerous branches, both to the intestines and digestive gland. The next branch proceeds from the same side of the artery, continuing to the digestive gland, giving off numerous branches and finally forming a network in the lobes of the digestive gland (pl. 18, fig. 9).

The next branch is from the opposite side of the artery, and continues on the posterior part of the stomach. This branch is prominent. At about one half the distance from the artery to the ventral part of the stomach it bifurcates, one branch again bifurcating; one branch containing latero-anteriorly and the other dorso-anteriorly. The main branch continues to the ventral part of the stomach, bifurcating; the branches continuing mainly on the ventral part of the stomach.

The next prominent branch is from the opposite side of the artery. The principal artery of this branch continues to a lobe of the digestive gland, and ramifies through it; a smaller branch continues to the intestine.

The next conspicuous artery is from the large artery which supplies the uterine canal and the so-called prostate gland.

Pulmonary cavity. The pulmonary cavity lies below the mantle and is of essentially the same shape. It is situated immediately below the shell cavity, and contains the heart, renal organ, the posterior part of the rectum and the anus. It is separated from the visceral cavity by the muscular peritoneum or diaphragm.

The respiratory orifice is situated on the right side of the body, at the edge of the mantle (pl. 23, fig. 1, *1*). This orifice opens and closes at regular intervals; the normal respiration seems to be from 16 to 18 times a minute, though it is frequently variable. When open the orifice is circular, and is closed by muscular fibers which surround it.

The pulmonary veins, or rete, are situated mostly on the roof of the cavity. They are numerous, anastomosing, and occupy nearly the whole surface (pl. 19, fig. 2).

Veins. The veins are situated mostly in the substance of the

body, not being on the surface as is frequently the case with the arteries. As in P. albolabris, they are not simply lacunae or spaces in the body, but have a distinct wall.

The branches of the arteries grow smaller and smaller, and finally consist of an anastomosing network, which communicates with a similar network of veins; these capillaries gradually coalescing, forming larger branches, which combine to form large veins, connecting with the sinus of the pulmonary cavity. There are two veins parallel with, and in close contiguity to the pedal gland or sinus.

The two largest veins are situated in the integument of the sides of the body, one on each side. They are connected with the arteries by innumerable ramifications. They are illustrated on plate 18, figures 2 and 3; but only the large vessels are shown, the smaller ones not being represented. There are also smaller veins in the lateral anterior parts of the integument, and a large vein in the dorsal part of the integument.

The blood proceeds from the heart through the arteries, entering the veins from the arteries, and carried by them to the renal organ and the pulmonary cavity, where it is aerated, and returned by the large pulmonary veins to the auricle, thence to the ventricle.

Kidney. The kidney is situated in contiguity to the heart (pl. 19, fig. 3), and is a large subovate, glandular organ. From the lower right side proceeds a duct, which continues along the lower part of the pulmonary cavity to the rectum, continuing alongside of this; curving near the extremity, the parts of the curve being in apposition to the rectum, and opening in close contiguity to the anus.

Nervous system

Plate 22

The two principal ganglionic masses are the supra and infra-esophageal (*1*, *2*).

The supra-esophageal ganglia are situated above the esophagus, and just posterior to the buccal body, when the animal is extended. Of course when the animal is contracted the relative positions are altered. The ganglionic mass consists of three pairs

of ganglia; the three pairs being united by an extremely short broad commissural cord, which is very inconspicuous; the inner pair of ganglia having somewhat the appearance of coalescing.

The outer pair are larger than the others and somewhat obscurely kidney-shaped. The anterior margin being rounded and continuous; the posterior part being bilobed, the inner lobe larger than the outer.

The second, or median, pair of ganglia are in contact with the inner part of the first mentioned pair for their entire length. They are curved, broadest at the base, and tapering to a point, very narrow at their widest point.

The third, or inner, pair are nearly in contact at their anterior part, gradually diverging posteriorly. They are comparatively narrow, though twice the width of the second pair, and are about four times as long as wide. They are each obscurely divided into four lobes, of which the anterior is subtriangular, the posterior nearly round, and the remaining two subquadrangular.

The infra-esophageal ganglionic mass is much larger than the supra-esophageal, (2), and consists of six pair of ganglia, aggregated more or less in one mass.

With the exception of the first pair the ganglia are regularly bilaterally arranged; one of each pair being on opposite sides of a median line.

The first pair consist of a large and a small ganglion, the larger one being ovate with a length about equal to twice its greatest diameter. Immediately anterior to this is a small ganglion, about one third the size of the first mentioned ganglion.

The next pair are situated one on each side, and partially underneath the first pair. They are subovate in form and are about one and one half times the size of the first mentioned pair.

The next pair are each about the size of the first mentioned ganglion, and are oval or subovate in form, and are situated mostly underneath the second pair, their anterior ends projecting. The posterior ends of the second pair project, laterally, beyond the third pair.

The fourth pair are subovate in form and situated beneath the second and third pair.

The fifth pair are situated below the fourth pair. Their inner margins are nearly in contact.

The large cephalic artery passes through the ganglionic mass, bounded above and below by the third and fifth pair of ganglia, and laterally by the fourth pair.

The sixth pair are below the fourth and fifth pair of ganglia, and when the ganglionic mass is viewed from above are almost hidden from sight.

The ganglionic masses are connected by two pairs of commissural cords, the upper ones of which proceed from the second pair of the supra-esophageal ganglia, and continue to the under part of the fourth pair of infra-esophageal ganglia. The inferior pair of cords proceed from the posterolateral part of the lower lobe of the inner, or third pair of supra-esophageal ganglia, and continue to the lower part of the sixth pair of infra-esophageal ganglia.

Two smaller ganglia are situated near the dorsal surface of the posterior part of the buccal body, one on each side of the esophagus, just as it leaves the buccal body. They are comparatively small, a little less than three times as long as wide, and are divided into three nearly equal lobes, (*3*) the anterior one being broader and shorter than the other two, which are nearly round. The two ganglia are connected by a strong commissural cord proceeding from the posterior lobes.

The buccal ganglia are connected with the cerebral ganglia by two commissural cords, which proceed from the under surface of the inner pair of cerebral ganglia, to the outer and under part of the anterior lobes of the buccal ganglia.

There are ganglionic swellings in the extremities of both the superior and inferior tentacles. That in each superior tentacle is digitate in form, the palm being exaggerated in size and the fingers short. From each of these processes, or fingers, numerous fibers proceed to the thin integument at the end of the tentacle. The ganglia of the inferior tentacles are pyriform, the largest end being nearest to the extremity of the tentacle, and giving off numerous fibers to the extremity of the tentacle.

A small ganglion is situated near the first branching of the

aorta on the dorsal part of the stomach. It is subovate in form, gradually enlarging from its posterior to its anterior extremity, and is about four times as long as wide (*4*).

From the outer anterior part of the principal ganglia proceeds a stout nerve to the extremity of the superior tentacle (*5*). Within the tentacle this nerve gives origin to a slender nerve proceeding to the eye, the optic nerve. From a point closely contiguous to the first mentioned nerve, but nearer to the anterior margin, proceeds a nerve, smaller than the first, which near the anterior extremity of the animal bifurcates, one branch going to the mouth (*7*), the other to the ganglia at the extremity of the inferior tentacle (*6*). From a point slightly nearer to the anterior margin proceeds a nerve, which near the mouth bifurcates and gives off nerves to the mouth and adjacent parts of the integument (*7′*). From the anterior lobe of the inner ganglia nerves proceed to the muscles and integument of the superior pair of tentacles (*8*). From the inner part of the principal ganglia proceed commissural cords, which unite with the anterior lobe of the buccal ganglia (*3′*).

The posterior lobes of the buccal ganglia are united by a short, broad commissural cord (*3″*).

From the anterior lobe of each buccal ganglion arise two nerves, which proceed to the anterior part of the buccal body, giving off numerous branches (*9*).

From the inner part of each median lobe arises a nerve which continues posteriorly alongside the esophagus (*10*); and from the posterior lobe two nerves, which supply the posterior part of the buccal body (*11*).

The cephalic artery passes through the infra-esophageal ganglionic mass, the ganglia forming a ring, and in an uninjected specimen might easily be mistaken for a large nerve.

From the posterior part of the dorsal ganglia proceed five nerves, three of which are of nearly equal diameter; the other two are smaller. The one to the left is free for a short distance, then buries itself in the substance of the retractor muscles, continuing to the origin of the muscles in the muscular layer.

The median nerve is directed posteriorly to the right (*21, 21′*), and furnishes nerves to the pulmonary cavity, respiratory orifice and anus.

The nerve from the right of the ganglion continues posteriorly to the large artery, entering the foot, to a minute oblong ganglion (*4*). The ganglion gives off five nerves, of which the larger arises in the outer anterior part, and proceeds along the intestine in close contiguity to the artery.

Immediately anterior to this is a small nerve proceeding to the pulmonary cavity.

From the opposite anterior part proceeds a nerve supplying the hermaphroditic generative organs.

From the posterior part proceed two nerves supplying the stomach and digestive gland.

In the inferior part of each of the second pair of infra-esophageal ganglia arises a large nerve which passes posteriorly and outward, entering the integument just anterior to the pulmonary chamber; the branches of these nerves supplying that organ and the heart.

From the posterior part of these ganglia proceed two very large nerves, which continue to the postero-basal part of the animal, parallel to and at a short distance from the pedal gland, giving off several branches to the base of the foot (*12, 13′, 13″*).

In the inferior part of the other ganglia arise five other pairs of nerves (*15-19*), which are inserted in the integument at the sides; and other more numerous nerves, which are inserted in the foot.

Muscular system

Plates 19, 20

The principal muscles, viz, the retractor muscles of the anterior part of the body, the buccal body and the tentacles, have their origin in the inner muscular layer, just posterior to the pulmonary cavity on the right side.

They at first consist of two broad, flat, somewhat connected bands (pl. 19, fig. 1, 2). At about one half the distance to the nerve ganglia these bands are subdivided, giving origin to the

ocular tentacular muscles (*3*), and the retractor muscles of the buccal body (*5*). The superior, or ocular tentacular muscles, shortly subdivide, giving origin to the muscles of the inferior, or olfactory tentacles (*4*), which are much smaller than those of the ocular tentacles.

The muscular sheath of the supra-esophageal ganglia is connected with the superior tentacular muscles by two flat muscular bands on each side (pl. 20, fig. 1, *2*).

In the anterobasal part of the animal arises a set of three muscles on each side (pl. 19, 20, fig. 1), the posterior one (*1*) arising under the muscles of the superior tentacle, and inserted near the lips of the animal. The middle one (*8*) is inserted in the muscles of the inferior tentacle. The anterior and largest muscle (*9*) passes over the superior tentacle muscles and is inserted at the mouth.

Posterior to these a muscle on each side has its origin in the basal part of the animal, and is inserted in the muscle of the inferior tentacle (*10*).

In figure 2, plate 20, the retractor muscles have been cut close to the buccal body, and that organism has been turned forward to show its under side, and also the base of the anterior part of the body cavity.

On each side of a basal median line, and at a short distance from it, a thin, flat band of muscular fibres arises, which is inserted at the extreme anterior end of the body at the mouth, immediately below the anterior end of the buccal body (*1*). These two bands of muscles, at their anterior part cross each other at an angle of about 45°. Their function is to contract the basal part of the anterior portion of the body.

On each side of the buccal body the lower part of the lateral lips can be observed, showing as a white mass, somewhat regularly longitudinally divided. From the posterior part of each mass proceed two muscles, one broad, the other narrow, uniting with the muscles of the inferior tentacle (pl. 19. fig. 2, *3*).

On the right side of the figure the lip and its muscles are shown in their natural position; on the left side of the figure the lip and

its muscles, as well as the muscle of the inferior tentacle, are turned forward in order to show a short, broad muscle, which has its origin in the anterior basal part of the body, and is inserted principally in the muscles of the inferior tentacle, but some of the fibers are inserted in the large muscles of the lip (pl. 20, fig. 2, *4*).

On the under side of the buccal body, toward the posterior part, are several moderately broad, horizontal bands of muscles, which are partially concealed by overlying longitudinal muscles (*10*). Bands of muscles are situated on the ventral surface of the buccal body, proceeding from the posteroventral part and diverging to the sides (*6*). Strong bands of muscles originate in the middle ventral part of the buccal body, and, slightly diverging, are inserted in the anterobasal part of the animal, just under the anterior part of the buccal body (*5*). A band of muscles is situated on each side of the buccal body, proceeding from the posteroventral to the anterolateral part of the buccal body (*7*).

Numerous fibers have their origin in the anterior part of the buccal body, and are inserted in the integument of the mouth. The entire outer walls of the buccal body are composed of muscular fibers, both transverse and longitudinal.

Looking down on the buccal body, the following muscles can be observed: a pair of delicate muscles, one on each side, arising in the inferior posterolateral part of the buccal body, and inserted in the cephalic integument; another delicate pair arising in the anterolateral part of the buccal body, and inserted in the integument, near the base of the inferior tentacles; a pair which proceed laterally from the anterior basal part of the buccal body, being inserted in the integument each side of that body.

The integument or skin of the animal is composed of two layers, the inner of which is composed of interlaced muscular fiber; and the viscera are inclosed by a very thin muscular peritoneum. The first layer is composed of unstriped muscular fibers, arranged transversely, longitudinally and obliquely.

The peritoneum is composed of muscles arranged transversely and longitudinally, and gives rise to the retractor muscles previously described.

EMBRYOLOGY OF LIMAX MAXIMUS

When the ova have reached a certain stage of maturity they leave the ovary. This process is known as ovulation. They pass through the hermaphroditic duct (pl. 16, fig. 1, *10*), to the albumen gland (*9*), and thence to the oviduct (*7*); from which they are discharged, that is, laid.

The composition of the egg is as follows: in the interior of the egg is the germinative vesicle, or egg nucleus, which contains a still smaller vesicle, or germinative dot; surrounding these is the yolk, which is a liquid of varying consistency. In the snail it is transparent. These parts of the egg are formed in the ovary. The albumen surrounds the yolk, and in the case of Limax is semitransparent, less so than the yolk. This substance is not formed in the ovary, but is secreted by the albumen gland (pl. 16, fig. 1, *9*). The albumen is surrounded by a membrane, which in Limax is semi-transparent, so that, when the egg is viewed under the microscope by transmitted light, the movements of the embryo can be observed, though not distinctly enough for study.

In the eggs of the Polygyra the outer covering is still membranous, though much thicker than in Limax, and it is opaque. After the escape of the young Polygyra, it has very much the appearance of a calcareous shell.

Soon after fertilization the egg undergoes the process of segmentation, that is breaks up into cells. It first divides into four equal cells; and then smaller cells are formed from the division of the first four, so as to lie outside of them. The smaller cells now subdivide and spread over the first four. The cell mass is dilated, becoming hollow. The large cells subdivide and sink into the hollow of the sphere, forming an elongated groove, the origin of which at the surface is known as the blastopore. This orifice subsequently closes up. The invaginated cells, formed by the subdivision of the large cells, are known as the endoderm. The outer layer, formed by the division of the smaller cells, is known as the ectoderm. This condition of the egg forms the gastrula stage (pl. 24, fig. 10-14).

A dilatation of the ectodermal walls now takes place, a con-

siderable space being left between the ectoderm and endoderm (pl. 25, fig. 6 and succeeding figures).

The body of the animal as first observed consists of a slight swelling of the upper side of the cell mass (pl. 25, fig. 7).

In the following descriptions it must be remembered that the ventral surface of the animal is uppermost.

The swelling above mentioned very soon shows a tendency to divide into two parts (pl. 25, fig. 9, and pl. 24, fig. 17), the anterior part of which is the foot proper, the posterior part the mantle, shell sac, etc.

Even at this early stage the embryonic shell can be observed, consisting of a few dark colored crystalline plates, not yet united.

At this stage the mouth appears at the position formerly occupied by the blastophore; which has disappeared or been closed, and consists of an invagination of cells, bounded by lateral lips (pl. 24, fig. 20).

The shell sac and mantle enlarge much the faster proportionally, as shown in plate 25, figures 11, 12.

In figure 12, and more distinctly in figure 13, the development of the tentacles is shown, which at this stage have the appearance of flat circular disks.

The body is very small; from its extremity a circular semi-transparent appendage, the podocyst, is developed, consisting of two walls, which are connected by reticulated muscular cells. The body now rapidly develops, as shown in figures 15 and 16, plate 25.

The shell has also increased in size, consisting of numerous crystalline plates, not yet united.

The ectodermal sac and podocyst have also increased in size. The surface markings are now apparent, and the beating of the heart is plainly visible beneath the mantle.

The smaller tentacles, the lateral lips of the mouth, the odontophore and the beginning of the alimentary canal have appeared; the pedal sinus is also apparent.

At this stage (pl. 25, fig. 17-21), the ectodermal sac and podocyst have reached their greatest development, and hereafter gradually diminish in size till completely absorbed.

The podocyst is now an object of great beauty, to which no drawing can do justice. It undergoes a rhythmic movement of dilatation and contraction, sometimes being so expanded as to include the rest of the embryo, then contracting to less than one half that size. The ectodermal sac also undergoes a similar contraction and expansion, sometimes in harmony with, and again alternating with that of the podocyst.

The whole embryo, from the stage represented by figure 11, has a rotatory motion.

In the stage represented by figure 19, I have first observed the "primitive kidneys." They are situated on each side of the endoderm, and consist of a series of curved elongate cells, within which concretions are developed, and terminate in a duct (pl. 28, fig. 4).

The cells proper are apparently angular or of different shapes (pl. 28, fig. 1, 2); but this is due to mutual pressure, as when the sac is ruptured the cells flow out perfectly spherical, as shown in figure 3.

As development proceeds a movement of the cells takes place from the ectodermal sac into the constantly enlarging body (pl. 26, fig. 1). The alimentary canal accompanies the cells; the anus alone remains in its original position.

In the stage represented by figure 5, plate 26, the ectoderm so closely bounds the endoderm as not to be apparent. The ectodermal cells have been largely absorbed into the body, or, rather, changed into body tissue, and the podocyst is very much reduced in size. The tentacles are assuming their mature form, and the mouth and lips are very distinct. The intestine is nearly complete and the larger endodermal cells have, in great part, been converted into the substance of the digestive gland. The respiratory orifice, the mantle and shell are well formed.

Heretofore the embryo has been represented with the ventral part uppermost, but in figure 2, plate 27, it is represented, in a reverse position, as in adult condition.

In this stage the endodermal cell mass has been almost entirely changed into the alimentary canal and its appendages, the podo-

cyst has been almost entirely absorbed, and the various organs are approaching their perfect condition. Figure 1, plate 27, represents the appearance of the embryo in the egg capsule at this stage (8). The absorption of the podocyst continues for a short time longer, when the animal becomes completely formed and emerges from the egg.

A careful study of the figures on plates 24-28, and their explanations, will perhaps show more clearly the development of the embryo than the preceding text.

It occasionally happens that there are two ova in one egg capsule, and in one instance I have observed four embryos in one egg capsule (pl. 27, fig. 4, 5).

Time of laying eggs

In the latter part of September I had a number of specimens sent to me. Within a very few days a majority of them laid eggs. Of course the very short time of confinement, only two or three days, made no difference in the time of laying. Others did not lay their eggs till the middle of November, when naturally they would have been hibernating for a month. It would seem therefore that some of the animals lay their eggs in the fall, and others not till the following spring.

The eggs are laid on the surface of the ground, under dead leaves, logs, stones, or any sheltered space, where the requisite moisture can be obtained. They are laid in a cluster. The number in the clusters observed by myself varied from 50 to 130. They are soft and before leaving the animal must be very much compressed; for a mass of eggs occupies a larger space than the animal itself. When first laid they are of beautiful appearance, semi-transparent, resembling globes of liquid. Light transmitted through them becomes a beautiful golden color. They are usually round, but sometimes oval, and when they are in apposition a part is frequently pressed in till it is concave, but, as the embryo grows, this part is pushed out, the egg becoming regularly round or oval.

It would seem probable that all eggs laid at the same time

would hatch out at about the same time, but I had several clusters of eggs laid within 24 hours of each other, kept in the same box, and necessarily under the same conditions, and when some of these were hatched out, the embryos of other clusters were not more than half developed. This statement has been questioned, but I am absolutely sure of the correctness of my observations in this respect.

Several of the clusters had not been fertilized, as shown by the non-development of the embryo.

Binney declares that eggs that had been several times subjected to a great heat in an oven, so as to become perfectly dry and shriveled, when placed in a moist place regained their lost form, and young were produced from them. While not doubting this statement, my experience has been that, when the egg became dry and shriveled, the embryo was killed; though when supplied with moisture the vitality under adverse circumstances was wonderful.

Embryos that I have dissected from the egg and placed in water retained life from 24 to 48 hours. Even when the power of motion was lost, the heart continued to beat.

Rate of growth

Even under the same conditions the rate of growth of all the animals is not uniform. I have at this writing more than 100 animals that were hatched at about the same time. They have been kept in the same box and of course under the same conditions. But they vary decidedly in size, some being not more than half the size of others.

At least two seasons are required for an animal to reach maturity. I have now specimens that were hatched nearly 10 months ago, which have been kept in a warm room during cold weather, therefore not hibernating, and supplied with an abundance of food; yet some of them are not half grown. They probably developed as rapidly as in natural conditions. Naturally they would hibernate during cold weather, and the growth would not be as great in 10 months as in confinement.

EXPLANATION OF PLATES

Polygyra albolabris

PLATE 1

FIG.

1-3 Dorsal, profile and ventral views of an adult shell, natural size.

4 A profile view, showing a more flattened form than in fig. 2.

5, 6 Ventral and profile views of a young shell, the peristome being as yet unformed.

7 Ventral view of an adult shell, showing the form of the under side of the peristome.

8 Profile view of a shell just after leaving the egg, x 10, the perpendicular line to the left of the figure showing the natural size. Figures 9, 10 and 11 are also enlarged, the perpendicular lines to the left of the figure showing the natural size as in fig. 8.

9-11 Showing succeeding stages of the form of the shell before reaching maturity.

12 An adult shell.

13 In this figure a part of the lower volution of the shell is broken away to show the interior.

14 A section of a shell. The outer part of the shell is ground away in order to show the columella.

15 A section. The columella has been ground down to show its interior.

PLATE 2

FIG.

1 An egg natural size and enlarged.

2 A view showing the shell within the egg.

3 A view showing the shell emerging from the egg.

4 Dorsal and profile views of a shell, newly hatched, natural size and enlarged.

Fig.

5, 6 Profile and ventral views of a shell about one month old, natural size and enlarged.

7 Dorsal and lateral views of a shell about three months old, natural size.

8, 9 The same, x 3.

10 Surface of the shell, x 10.

11 The same, x 20.

12 Transverse section of the prismatic layer of the shell, x 100.

13 A section of a part of the peristome, x 40.

14 A section of the peristome and a part of the shell, x 10.

15 A section of the shell; cuticle; outer layer; median layer; inner layer.

16 A section of the volutions, x 2.

17 One volution more highly magnified, x 6.

18 A transverse section of the peristome, x 2.

PLATE 3

Fig.

1 Dorsal view of a shell and extended animal. The smaller figure represents a newly hatched animal. Both figures are natural size.

2 Profile view of shell and extended animal, natural size.

3 An animal from which the shell has been removed, showing protruding penis; *1* penis; *2* anus; *3* stomach; *4* ovotestis; *5* intestine; *6* digestive gland; *7* kidney; *8* pulmonary vein.

4 The same view as in figure 3, the volutions being partially uncoiled to show the position of the generative organs. For explanation of the organs see plate 23, figure 9.

5 Ventral view, the animal being retracted within the shell; *1*, respiratory orifice.

6 Laterobasal surface of the integument, x 6.

7 A part of the integument of the dorsal part of the foot, x 6.

PLATE 4

FIG.

1 The buccal body, enlarged, from above; *1* the buccal body; *2* esophagus; *3* salivary ducts; *4* nerves uniting cerebral and buccal ganglia; *5* retractor muscles; *6* depressor muscles; 7 levator muscles; *8* protractor muscles; *9* labial muscles.

2 The buccal body. The dorsal wall is cut through, and separated, displaying a part of the interior; *1* buccal body; *2* muscular wall of the buccal body; *3* lateral lips; *4* radula, or lingual ribbon; *5* sac of radula; *6* esophagus; *7* salivary duct.

3 The buccal body laid open, from above; *1* lateral lips; *2* muscular wall of the buccal body; *3* odontophoral cartilage; *4* radula; *5* sac of radula; *6* retractor muscles.

4 Longitudinal section of the buccal body; *1* odontophoral cartilage; *2* radula; *3* sac of radula; *4* muscular wall; *5* jaw or dental plate; *6* esophagus; 7, *8* muscles connected with the radula; *9* opening of the pedal sinus; *10* pedal sinus; *11* muscular sole of animal; *12* infra-esophageal ganglia; *13* supra-esophageal ganglia; *14* retractor muscles; *15* tentacular muscle.

5 A section of the animal showing: *1* pedal sinus; *2* large veins; *3* small veins; *4* mucus glands; *5* muscular sole of foot.

6 Perpendicular section of the buccal body; *1* esophagus; *2* salivary ducts; *3* lingual ribbon or radula; *4* sac of radula; *5* odontophoral cartilage.

7 Vertical section, the same as figure 6, the esophagus, etc., have been removed, bringing into view the radula; *1* radula; *2* odontophoral cartilage.

PLATE 5

FIG.

1 A view from the under side of the head, showing the mouth and lips, x 5.

2 The jaw, x 10.

3 The digestive organs; *1* the buccal body; *2* esophagus; *2′* the crop; *3* salivary ducts; *4* salivary glands; *5* stomach; *6* intestine; *7* rectum; *8* anus; *9* digestive gland; *10* ducts of digestive gland; *11* ventricle; *12* auricle; *13* pericardium; *14* kidney or renal organ all x 2.

4 Crop and salivary gland, x 6.

5 Heart and kidney as seen from the exterior.

PLATE 6

FIG.

The lettering on each of the figures refers to the same organ.

1-6 Transverse sections of the body from the buccal body to near the posterior extremity of the foot.

1 genital opening; *2* penis; *2′* sac of radula; *3* esophagus; *4* salivary duct; *5* tentacular muscles; *6* vas deferens; *7* peritoneum; *8* pedal sinus; *9* oviduct; *10* vagina; *11* uterine canal and spermatic duct; *12* the mantle.

7 The stomach and a part of the intestine as seen from above

8 The stomach as seen from below, showing also the ducts of the digestive gland and their connection with the stomach.

PLATE 7

Generative organs

FIG.

1 *1* genital aperture; *2* penis; *3* outer fold or prepuce; *4* vagina; *5* receptaculum seminis; *6* vas deferens; *7* free oviduct; *8* uterine canal; *9* spermatic duct; *10* talon, or accessory gland of the hermaphroditic duct; *11* hermaphroditic duct; *12* ovotestes; *13* retractor muscle of the penis; *14* albumen gland, all x 3.

FIG.

2 An enlargement of a part of the generative organs: *1* hermaphroditic duct; *2* talon; *3* albumen gland.

3 Accessory gland, or talon, seen from above, x 6.

4 The same as seen from below, x 6.

5 The ovotestes, x 5.

6 The cecal tubes of the ovotestes, x 30.

7 A transverse section of the ceca of the ovotestes, showing the spermatic within the ovarian tube, x 30.

PLATE 8

FIG.

1 An exterior view of the penis, x 3.

2 A longitudinal section of the penis, showing the corrugated fold, or pilaster, of the interior, and the manner of the formation of the outer fold, or prepuce, x 3.

3 The penis opened from the dorsal part, showing the corrugations of the lining membrane, and the corrugated fold, pilaster, of the membrane, x 3.

4 A part of the corrugated and papillate lining membrane, x 10.

5 A transverse section of the vas deferens, x 6.

6 A tranverse section of the vas deferens, showing its entrance into the penis, x 6.

7-9 Sections of the penis, figure 9 being beyond the pilaster, x 6.

10 An exterior view of the vagina and receptaculum seminis, x 4.

11 A longitudinal section, showing the muscular folds of the vagina, x 4.

12 A transverse section of the vagina, and of the oviduct at its entrance into the vagina, x 6.

13 A transverse section of the vagina at the point indicated by the dots in figure 11, x 6.

14 A transverse section of the receptaculum seminis, x 6.

PLATE 9

Arteries

Circulatory system, 1 auricle; *2* ventricle; *3* posterior aorta; *4* anterior aorta; *3′* artery to albumen gland; *3″* artery to digestive gland; *6* artery to stomach; *7* artery to hermaphroditic duct; *8* artery to uterine canal and spermatic duct; *9* artery supplying muscular collar, pedal muscles and crop; *10* artery to pedal muscles; *11* artery to muscular collar; *12* artery supplying crop; *13* arteries to salivary ducts; *14* artery to base of foot; *15* artery supplying nerve commissures; *16* arteries to the tentacles; *16′* artery to buccal body; *17* artery to vagina; *18* artery to the penis; *19* artery to the intestine; *20* artery to the ovotestes.

PLATE 10

FIG.

1 *1* Pericardial cavity; *2* auricle; *3* ventricle, x 6.

2 Showing the stomach and under or inner face of the digestive gland, and the arteries supplying that part of the animal: *1* auricle; *2* ventricle; *3* stomach; *4* intestine; *5* ducts of digestive gland; *6* artery to the smaller or superior lobe of the digestive gland; *7* arteries to the ovotestes; *8* kidney; *9* rectum; *10* digestive gland, x 3.

3 The outer part of the digestive gland and its arteries.
The numbering has the same signification as in figure 2.

4 The stomach and its arteries, x 3.

5 The crop and salivary gland and their arteries, x 3.

6 Showing the arteries of the ceca of the ovotestis.

PLATE 11

FIG.

1 An enlargement showing the heart and the veins of the pulmonary cavity: *1* auricle; *2* ventricle; *3* the large pulmonary vein leading to the auricle; *4* the afferent veins; *5* the efferent veins; *6* the large vein or venous sinus incircling the pulmonary cavity.

FIG.

2-4 Figures showing the position of the pulmonary cavity, in relation to the volutions of the animal.

PLATE 12

Nervous system

a supra-esophageal or cerebral ganglia; *b* infra-esophageal ganglia; *c* commissures connecting the supra and infra-esophageal ganglia; *d* nerves to the ocular or superior tentacles; *e* ganglionic enlargement at the extremity of the ocular tentacles; *f* optic nerve; *g* eye; *h* nerves to olfactory, or inferior, tentacles; *i* ganglionic enlargement at the extremity of the inferior tentacle; *k* nerve to mouth; *l, m* nerves supplying the mouth and adjacent parts; *n* buccal ganglia; *o* commissural cords connecting the supra-esophageal and buccal ganglia; *p* nerves supplying the generative system and the visceral mass; *r* nerves to the muscular collar and pulmonary cavity; *s* nerves supplying the basal parts of the animal; *t* nerves supplying the laterobasal parts of the foot; *u* nerves to the integument on each side.

PLATE 13

The same lettering refers to the same muscles in each figure.

FIG.

1-2 The retractor muscles of the buccal body, foot and tentacles enlarged. *1* retractor muscles of the buccal body; *2* retractor muscles of the foot; *3* retractor muscles of the ocular tentacles; *4* muscles continuing to the lips and tentacles; *5* muscles of olfactory tentacles; *6* muscles of mouth; *7, 8, 9* muscles of the buccal body; *7* levator muscle; *8* protractor muscle; *9* depressor muscles. Figure 1 shows the muscles as seen from above; figure 2 is a lateral view.

3 An enlarged section of the tentacles: *1* integument; *2, 2′* tentacular muscles; *3, 3′* tentacular nerves; *4, 4′* tentacular ganglia; *5* optic nerve; *6* eye; *7* muscles to the mouth; *8* nerves to mouth.

FIG.

4 An enlargement of the ganglion of the ocular tentacles, optic nerve and eye, x 12.

5 An enlargement of the nerve and ganglion of the olfactory tentacle, x 12.

6 Cryptoicus minutissimus, highly magnified.

PLATE 14

Polygyra albolabris dissected and the organs separated: *1* buccal body; *2* esophagus; *3* crop; *4* stomach; *5* intestine; *6* rectum; *8* anus; *9* superior lobe of digestive gland; *10* inferior lobe of digestive gland; *11* ducts of digestive gland; *12* salivary ducts; *13* salivary glands; *14* penis; *15* vagina; *16* receptaculum seminis; *17* retractor muscle; *18* glandular portion of the vas deferens; *19* vas deferens; *20* spermatic duct; *21* uterine canal; *22* spermatic duct; *23* albumen gland; *24* hermaphroditic duct; *25* accessory gland of duct, or talon; *26* ovotestes; *27* renal organ or kidney, the primary ureter along its upper side; *28* secondary ureter; *29* opening of ureter, or renal duct; *30* ventricle; *31* auricle; *32* pericardiac cavity; *33* pulmonary vein; *34* large blood vessel connecting with pulmonary rete; *35* pulmonary rete; *36* supra-esophageal ganglia; *37* tentacular nerve; *38* nerves to mouth and inferior tentacle; *39* superior tentacles; *40* integument; *41* muscles from buccal body of integument; *42* superior tentacular muscle; *43* inferior tentacular muscle; *44* retractor muscles; *45* muscular peritoneum; *46* muscular collar; *47* cephalic artery; *48* nerve to muscular collar.

PLATE 15

Limax maximus

The same letters apply to the same organ in each figure.

FIG.

1 The dorsal part of the integument is cut and turned back, showing the various organs in position.

2 The pulmonary chamber, heart, etc. are turned back, showing the under side of the organs, and the parts concealed by them in figure 1.

FIG.

3 The organs are separated, and each organ is shown more distinctly. *1* buccal body; *2* salivary ducts; 3 salivary glands; *4* crop; *5* intestines; *6* rectum; 7 stomach; *8* digestive gland; *9* penis; *10* retractor muscle of the penis; *11* receptaculum seminis; *12* uterine canal; *12′* spermatic duct; *12″* albumen gland; *13* hermaphroditic duct; *14* ovotestes; *15* nerves to the basal part of the body; *16* large veins in the integument of the sides of the animal; *17* ventricle; *17′* auricle; *18* kidney; *19* duct of kidney; *20* pulmonary veins; *21* respiratory orifice; *22* insertion of retractor muscles; *23* tentacular muscles; *24* mantle; *25* integument; *26* arteries.

PLATE 16

FIG.

1 The under side of the head, showing the mouth; *1* anterior or upper lip; *2* lateral lips; *3* four corrugations of the integument surrounding the mouth; *5* triangular appendages.

2 View from above, the integument and dorsal part of the basal body cut open and turned back: *1* corrugations of the integument surrounding the mouth; *2* lateral lips; *3* buccal body; *4* jaw; *5* radula; *6* esophagus; 7 salivary ducts; *8* muscles of ocular tentacle; *9* muscles proceeding from the anterobasal part of the animal, and inserted in the olfactory tentacular muscle; *10* muscle proceeding from the anterobasal part of the animal to the mouth; *11* muscles of the olfactory tentacles; *12* muscles from integument to anterior part of buccal body; *13* penis.

3 Digestive organs, etc.: *1* buccal body; *2* esophagus; *3* salivary ducts; *4* salivary glands; *5* crop; *6* stomach; 7 intestine; *8* rectum; *9* anus; *10* arteries, x 3.

4 Enlargement of the under side of the upper salivary gland.

5 Dorsal view of an adult individual.

FIG.

6 Transverse section of a specimen: *1* mantle; *2* envelop of the shell; *3* shell; *4, 5* pulmonary veins; *6* pulmonary cavity; *7* mucous part of the integument; *8* muscular substratum of integument; *9* muscular peritoneum; *10* muscular and mucous basal integument; *11* visceral cavity.

PLATE 17

Generative organs

FIG.

1 *1* genital opening; *2* penis; *3* vas deferens; *4* spermatic duct; *5* retractor muscle of the penis; *6* receptaculum seminis; *7* free oviduct; *8* uterine canal; *9* albumen gland; *10* hermaphroditic duct; *11* ovotestes.

2 Penis retracted, x 3.

3 Penis exserted, x 3.

4 Ovotestes, x 4.

5 Ceca of the ovotestes, enlarged.

6 A still farther enlargement of the ceca.

7 A transverse section of the penis and vas deferens, x 6.

PLATE 18

Circulatory system, x 3

FIG.

1 *1* aorta as it leaves the ventricle; *2* anterior aorta; *3* arteries to the crop; *4* arteries to the uterine canal; *3″* arteries to the stomach, intestine and digestive gland; *5* artery to the lower salivary gland; *6* artery to upper salivary gland; *7* posterior aorta; *8* arteries to the intestine; *9* arteries to the digestive gland; *10* artery to ovotestes; *11* artery to penis; *12* artery to vagina and receptaculum seminis; *13* artery to buccal body; *14* artery to commissural cords; *15* arteries to tentacles; *16* artery to basal part of the body.

FIG.

2-3 Large lateral veins situated in the integument on each side of the body. Only the larger veins are shown, but they are connected with the arteries by a fine network of veins and capillaries, x 3.

4 Showing the arteries and veins of the large lobe of the digestive gland, x 3.

5 *1* pedal sinus; *2* lateral veins.

PLATE 19

Muscular system, x 4

FIG.

1 *1* origin of retractor muscles; *2* principal muscular bands; *3* retractor muscles of the ocular tentacles; *4* retractor muscles of the olfactory tentacles; *5* retractor muscles of the buccal body; *6* muscles proceeding from the olfactory tentacular muscles to the mouth; *7* muscles proceeding from the anterobasal part of the animal to the mouth; *8* muscles proceeding from the anterolateral part to the olfactory tentacular muscles; *9* muscles proceeding from the anterolateral parts of the animal to the mouth; *10* muscles proceeding from the anterobasal part to the olfactory tentacular muscles; *11* muscular fibers from the buccal body to the mouth.

2 Pulmonary veins, x 4.

3 Under side of the pulmonary cavity, x 4: *1* auricle; *2* ventricle; *3* pulmonary veins; *4* respiratory orifice; *5* kidney; *6* duct or secondary ureter of kidney; *7* anus.

PLATE 20

Muscular system, x 6

FIG.

1 *1* buccal body; *2* muscular sheath of ganglia; *3* muscles of the ocular tentacles; *4* muscles of olfactory tentacles; *5* muscles arising in the basal part of the animal and connecting with the olfactory tentacular muscles; *6* muscles arising in the olfactory tentacular muscles and connecting with the mouth; *7* muscle arising in the basal part of the animal, beneath the ocular tentacular

FIG.

muscles and connecting with the mouth; *8* muscles arising in the anterobasal part and connecting with the muscles of the olfactory tentacles; *9* muscles arising in the anterobasal part and connecting with the mouth; *11* muscular fibers from the buccal body to the lips; *12* muscles of the buccal body; *13* esophagus; *14* salivary ducts.

2 Buccal body turned back to show the muscles beneath: *1* broad oblique bands of muscles arising in the anterobasal part and inserted in the extreme anterior part of the animal; *2* ocular tentacular muscles; *3* olfactory tentacular muscles; *4* muscles arising in the anterobasal part of the animal, and inserted in the ocular tentacular muscles; *5* muscles arising on the under side of the buccal body and inserted in the lips; *6* oblique muscles of the under side of the buccal body; *7* retractor muscles of the buccal body; *8* retractor muscles; *9* pedal sinus and bordering veins.

PLATE 21

The numbering of the horizontal lines corresponds to that of the figures.

The same lettering refers to the same organ in all the figures.

Transverse sections of Limax maximus, x 3.

An outline showing the position of the sections.

The section, figure 1, was made at the place designated by line 1, and so on to figure 12.

0 salivary ducts; *0′* salivary glands; *1* mantle; *2* shell cavity; *3* shell; *4* kidney; *5* heart; *6* penis; *7* arteries; *8* receptaculum seminis; *9* uterine canal, spermatic duct and albumen gland; *10* crop; *10′* intestine; *10″* esophagus; *11* rectum near anus; *12* pulmonary vein; *13* respiratory orifice; *14* pedal sinus; *15* large lateral veins; *16* smaller lateral veins; *17* veins contiguous to and parallel with the pedal sinus; *18* digestive gland; *19* hermaphroditic duct; *20* ovotestes; *21* ocular tentacular muscles; *22* cartilaginous cushion supporting radula; *22′* radula.

PLATE 22

Nervous system

1 supra-esophageal ganglia; *2* infra-esophageal ganglia; *2′* commissural cords connecting the supra- and infra-esophageal ganglia; *3* buccal ganglia; *3′* commissural cords connecting the cephalic or supra-esophageal and the buccal ganglia; *3″* commissural cord uniting the buccal ganglia; *4* stomachic ganglia; *5* nerves to the ocular tentacles; *6* nerves to the olfactory tentacles; *7* nerves to the mouth; *7′* nerves to the lips and adjacent integument; *8* nerves to the integument of the integument of the ocular tentacles; *9* nerves to the anterior part of the buccal body; *10, 11* nerves to the posterior part of the buccal body; *12* large nerves running to the posterobasal part of the animal; *13, 13′* branches of the preceding; *14, 15* nerves from the pedal ganglia to the basal part of the body; *16-19* nerves from the pedal ganglia to the sides of the body; *20* cord connecting pedal and stomachic ganglia; *21* nerve to retractor muscles; *22* nerve to pulmonary cavity.

PLATE 23

FIG.

1 A profile view of a small specimen of Limax maximus: *1* respiratory orifice; *2* genital orifice.

2 The radula, profile view, x 6.

3 The same, as seen from above, x 6.

4 The jaw and its retractor muscle, x 6.

5 Dorsal view of upper salivary gland, x 3: *1* salivary duct; *2* arteries; *3* nerves; *4* artery to the stomach.

6 Lower salivary gland: *1* salivary duct; *2, 3* arteries; *4* nerve, x 3.

7 The digestive gland detached from the intestine, etc. dorsal view, x 3.

8 The same as seen from below; the points *a* are in apposition when the gland is in its natural position: *1* hermaphroditic duct; *2* arteries.

Fig.

9 Polygyra albolabris, showing the generative organs in situ: *1* genital opening; *2* penis; *3* vagina; *4* vas deferens; *5* spermatic duct; *6* uterine canal; *7* talon; *8* albumen gland; *9* hermaphroditic duct; *10* ovotestes; *11* salivary gland; *12* stomach; *13* rectum; *14* beginning of rectractor muscles; *15* buccal body; *16* tentacular muscles.

PLATE 24

Fig.

1 A group of eggs, natural size.

2-5 Various forms of eggs, x 4.

6, 7 Transverse sections of round and oval eggs.

8 The germinative vesicle, x 48.

9 The under side of the germinative vesicle at the beginning of segmentation, x 48.

10, 11 The ovum during segmentation as seen from above, x 48.

12 A side view of the same, x 48.

13 The segmented mass as seen from below, showing blastopore, endoderm and ectoderm, x 48.

14 A vertical section of the same, showing *1* the blastopore; *2* the archenteron; 3 cleavage cavity; *4* ectoderm; *5* endoderm.

15 Cells. The dark cells are from the ectoderm; the light from the endoderm, x 250.

16 Showing the endodermal cell mass surrounded by a transparent sac or wall, x 32.

17 Showing the early stages of the formation of the foot and shell sac, x 32.

18 A stage slightly more advanced, showing the beginning of the tentacles and shell, x 32.

19 A stage still more advanced showing the beginning of the podocyst at the extremity of the foot, x 32.

20 A view of the same, from below, showing the podocyst and the mouth of the animal, x 32.

PLATE 25

This plate shows the gradual development of the embryo from the germinative vesicle.

FIG.

1 The germinative vesicle within the egg, natural size and x 8.

2 Germinative vesicle, x 16.

3 Under side of same at the commencement of segmentation, x 16.

4 The segmented ovum, x 16.

5 The endodermal cell mass, inclosed by a transparent sac or wall of ectoderm, x 16.

6 Showing the transparent sac greatly developed on one side of the cell mass, x 16.

7 The beginning of the development of the body form, as shown by a slight elevation from the cell mass, x 16.

8 A stage slightly more advanced, x 16.

9 The elevation is divided into two lobes, representing the body proper and the shell sac, x 16.

10 The embryo within the egg, natural size and x 8.

11 A stage more advanced than in figure 9. The podocyst is here plainly shown, x 16.

12, 13 Still more advanced stages, x 16.

14 An embryo within the egg, x 8.

15 In this stage the tentacles are rapidly developing, the body and podocyst are distinct, and the development of the buccal body and alimentary canal has begun, x 16.

16-19 Gradual development of the embryo. In figure 16 the endodermal cell mass has reached its greatest size, gradually becoming absorbed in succeeding stages, x 16.

18 The embryo within the egg, showing the same stage as in figure 19, x 8.

20, 21 Ventral and profile views of the embryo within the egg, x 8; showing a stage more advanced than that represented by figure 19.

PLATE 26

FIG.

1 Showing the same stage as represented by figures, 20, 21 in plate 25. The podocyst in this stage reaches its greatest size, and in the succeeding stages rapidly diminishes in size, x 14.

2 Ventral view of an embryo of the same stage as represented in figure 1; showing the base of foot, tentacles, mouth, lateral lips and corrugations surrounding the mouth, x 25.

3 A profile view of the same, showing the tentacles and the "primitive kidney" on the side of the endodermal mass, x 30.

4 A more advanced stage, x 14.

5 A still more advanced stage. The tentacles have begun to assume their adult form; the internal organs are assuming definite form; and the endodermal mass and podocyst are greatly reduced in size by absorption, x 14.

PLATE 27

FIG.

1 Showing the position of the embryo within the egg just before emerging, x 8.

2 The same removed from the egg, x 16.

3 A fully developed specimen. The integument is cut along the dorsal line and drawn back, so as to show the internal organs. See plate 15 for a description of the various organs.

4 An egg containing two embryos, x 8.

5 An egg containing four embryos, x 8.

6 The tentacles and protruded mouth of an embryo; *ut* superior tentacle; *lt* lower tentacle; *bm* buccal mass; *dp* jaw; *m* retractor muscle of jaw, x 10.

7-9 Abnormal eggs. These are of frequent occurrence, x 4.

PLATE 28

Fig.

1 A group of cells after segmentation, greatly enlarged.

2 A group of cells at a later stage; the larger and smaller cells grouped in polygonal masses, and distorted from mutual pressure, greatly enlarged.

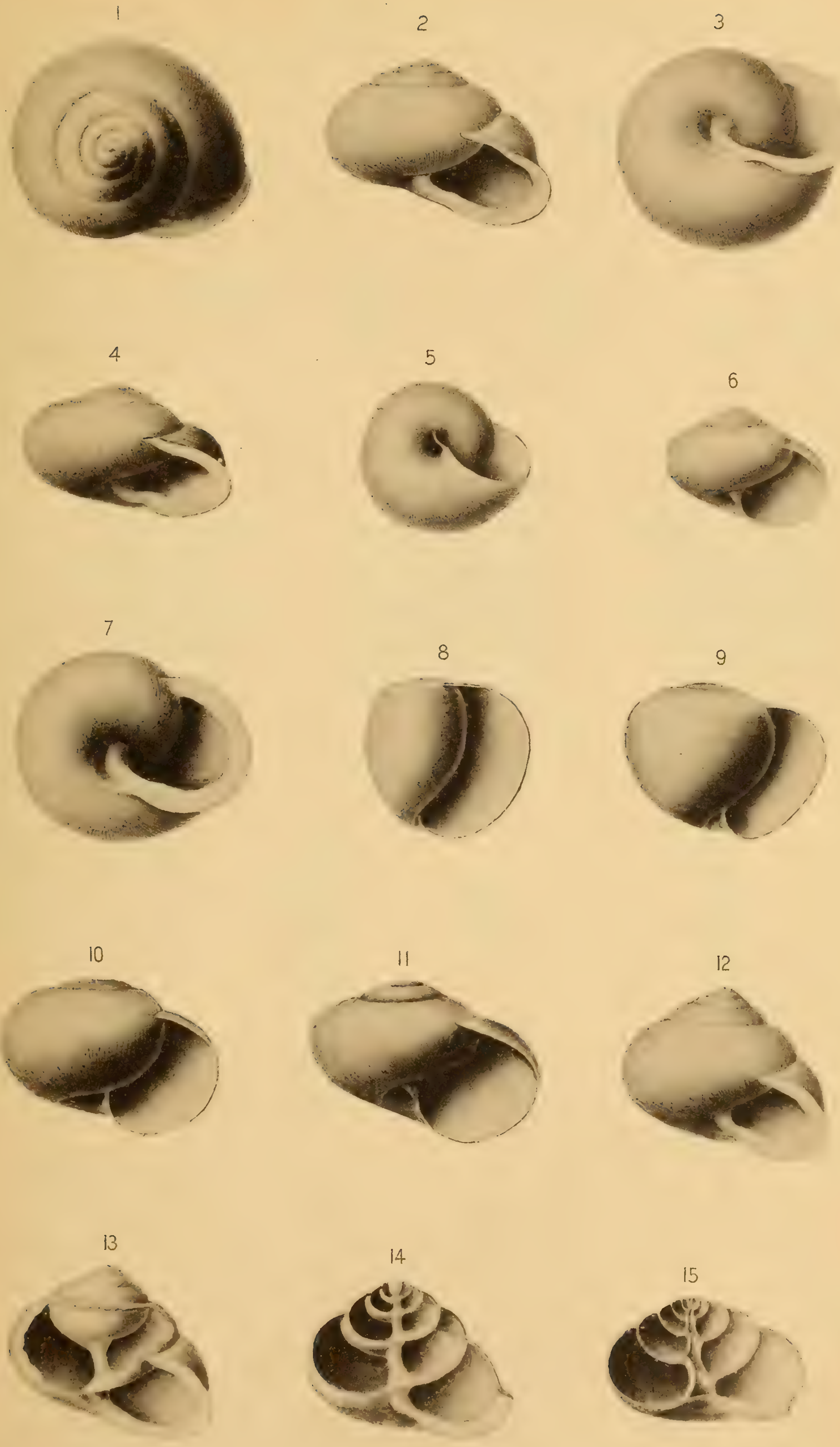
3 The cells liberated from one of the polygonal masses, showing their true form, greatly enlarged.

4 The primitive kidney showing the cells and their calcareous concretions, greatly enlarged.

5, 6 Groups of cells from the position indicated by the lettering *5* and *6*, figure 5, plate 26, greatly enlarged. The latter containing calcareous concretions as in the "primitive kidney."

7-13 Showing the gradual development of the shell, x 30.

14 The fully formed shell, dorsal view, x 2. The under side of the shell has very much the appearance represented in figure 13.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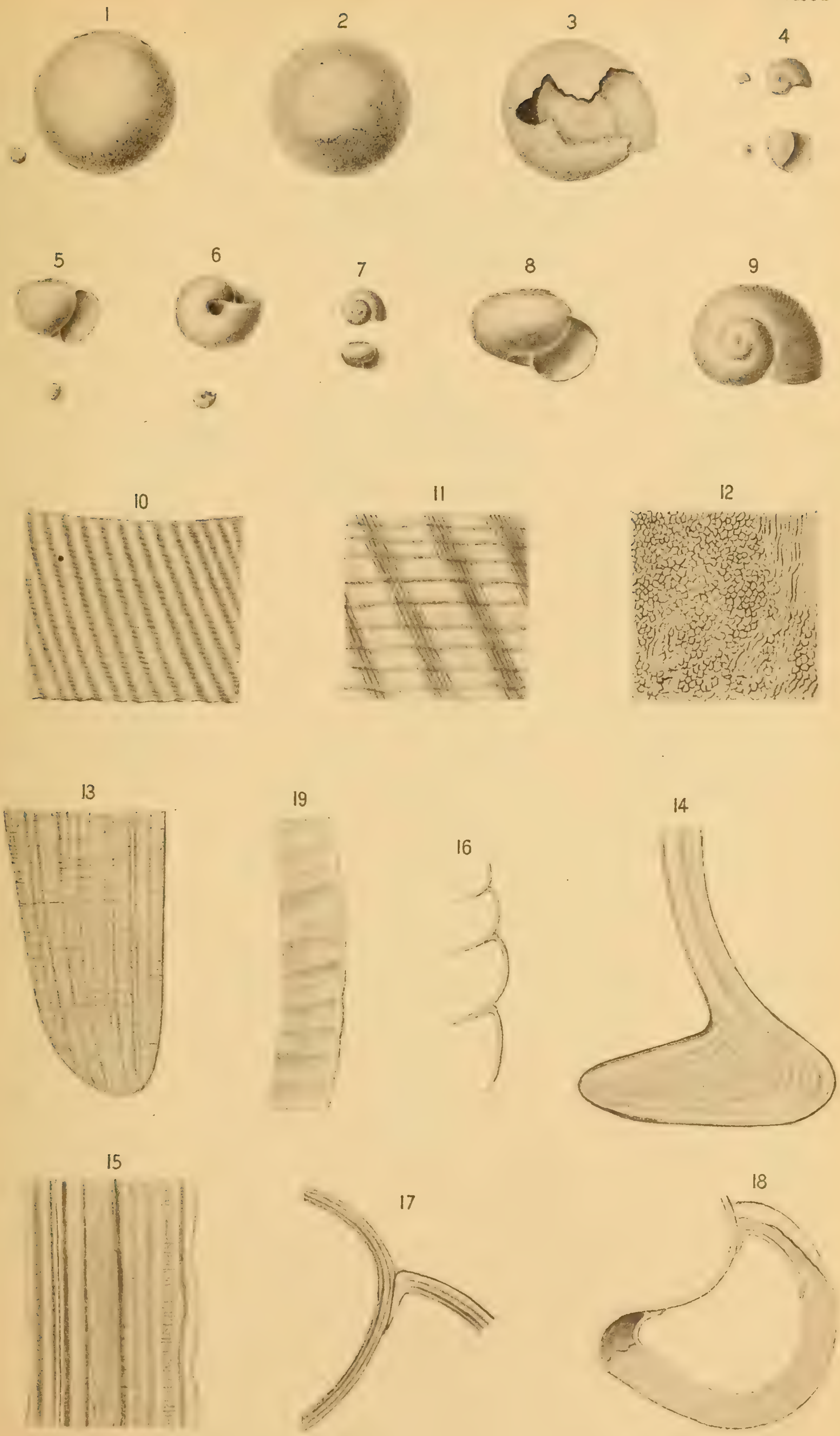

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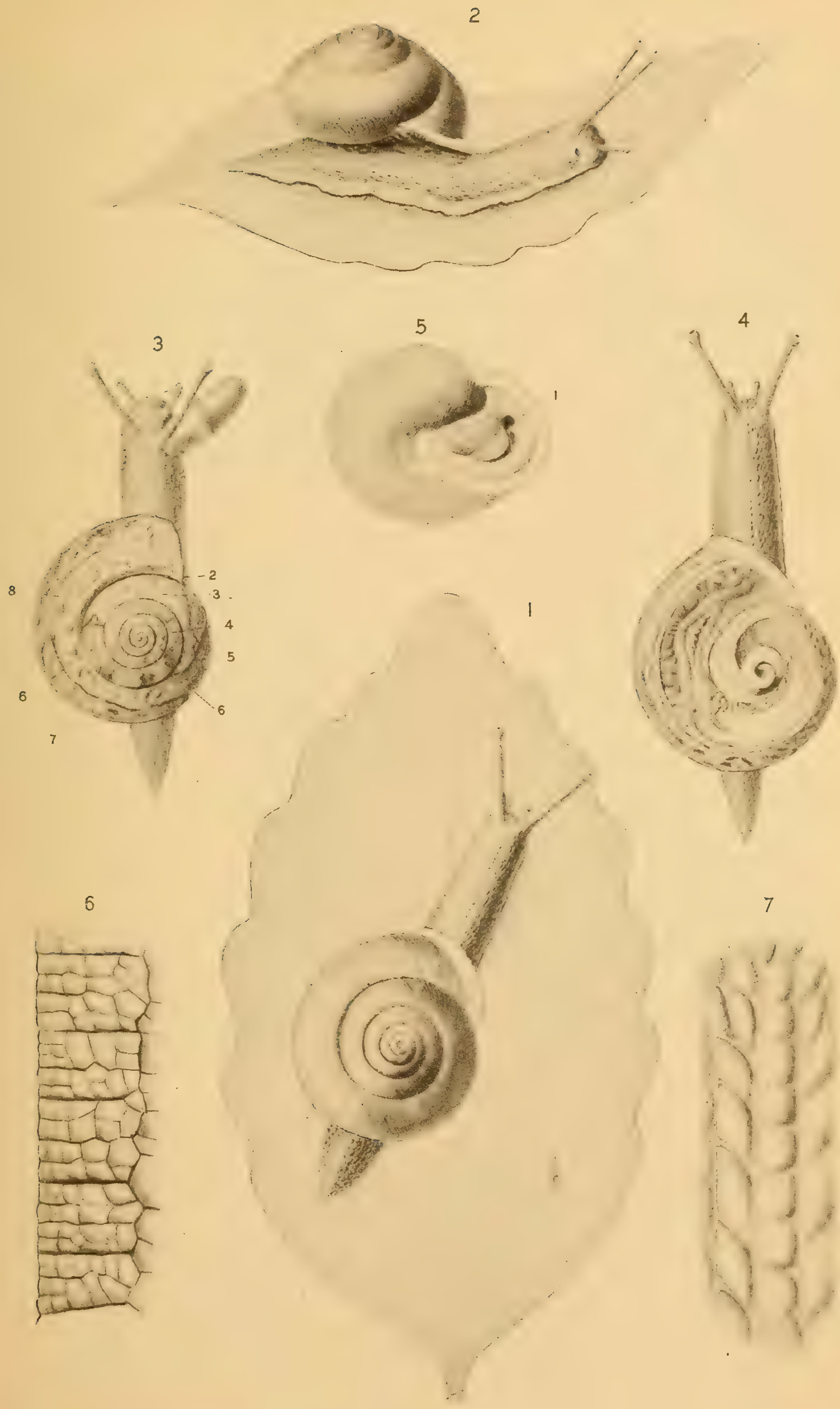

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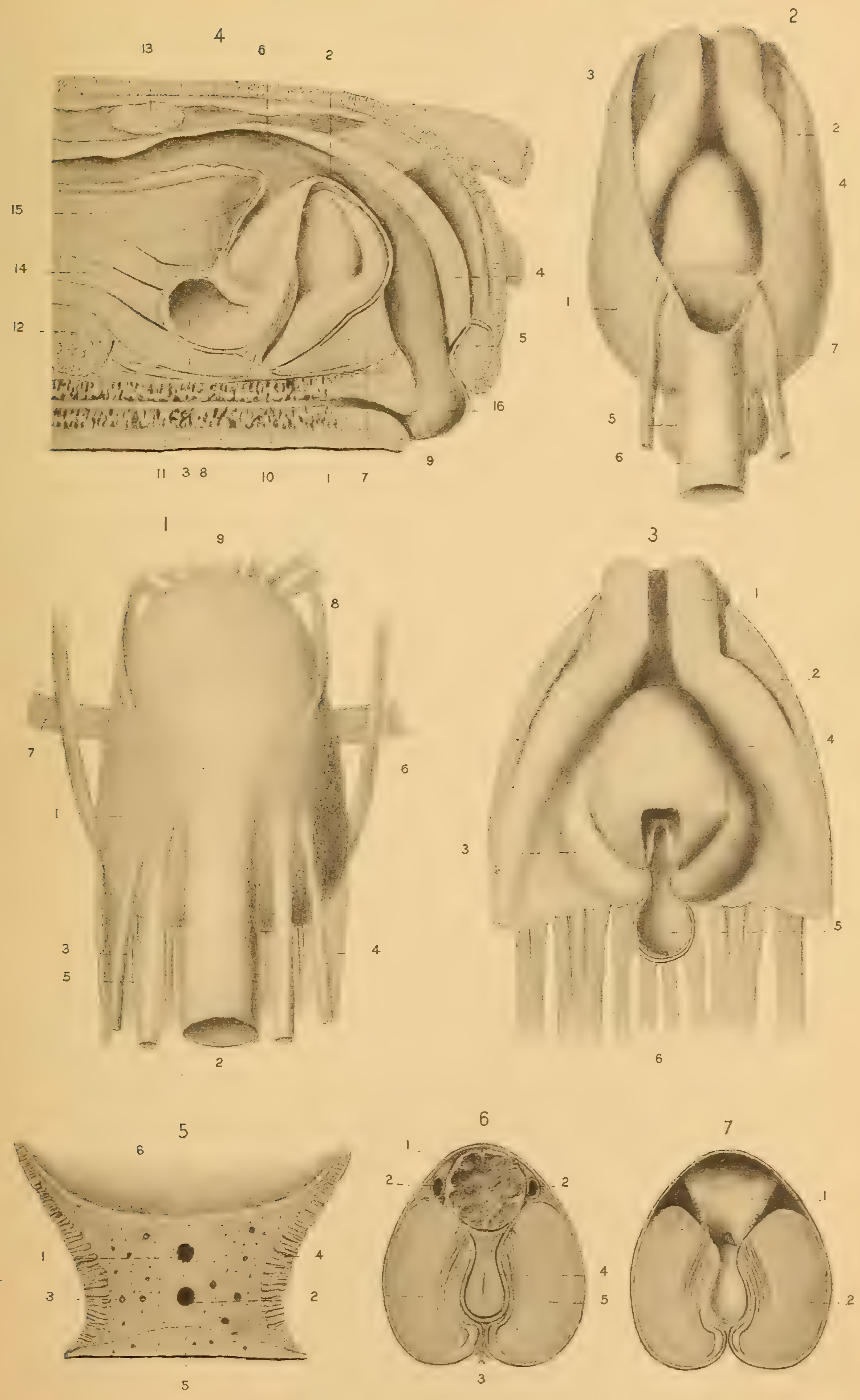

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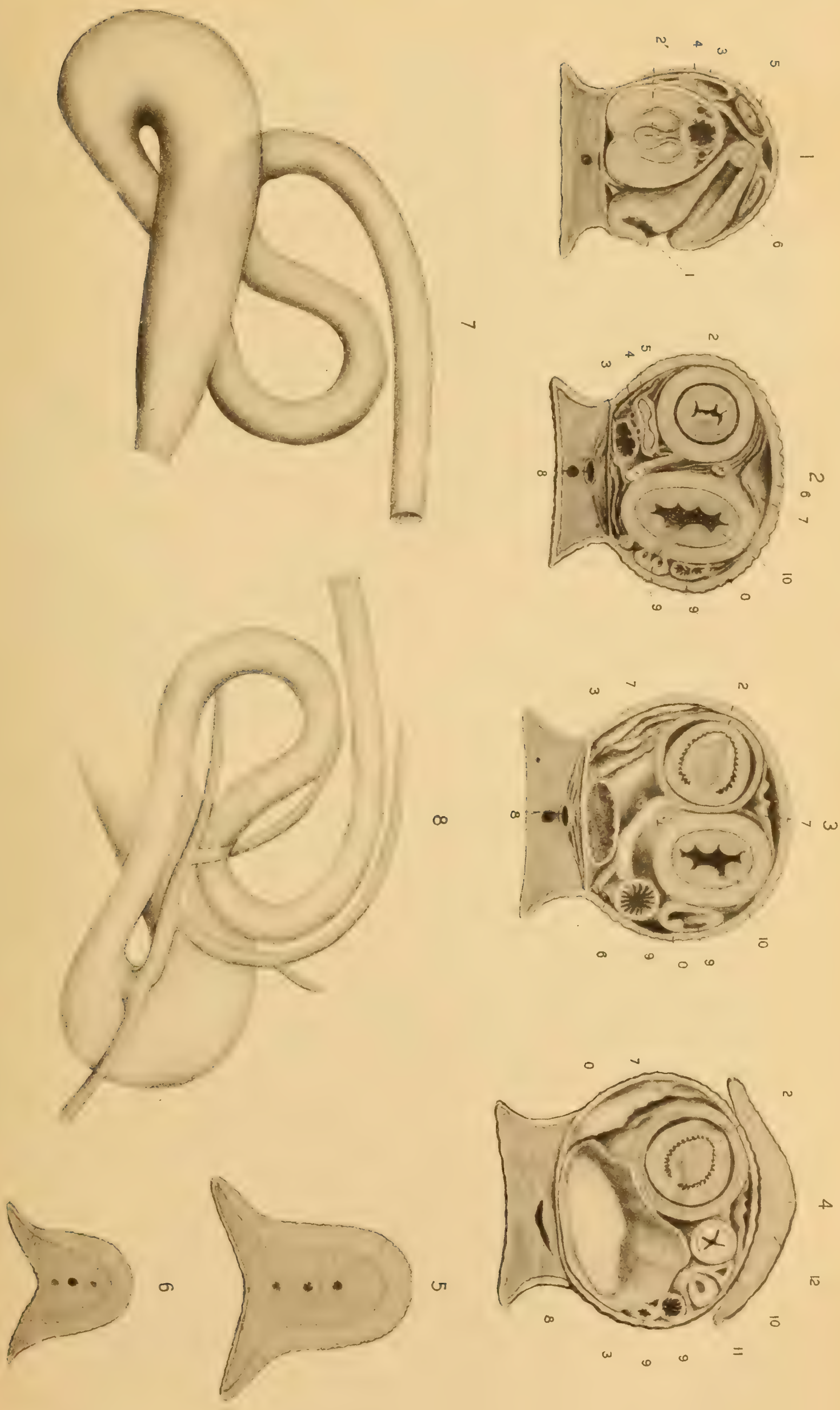

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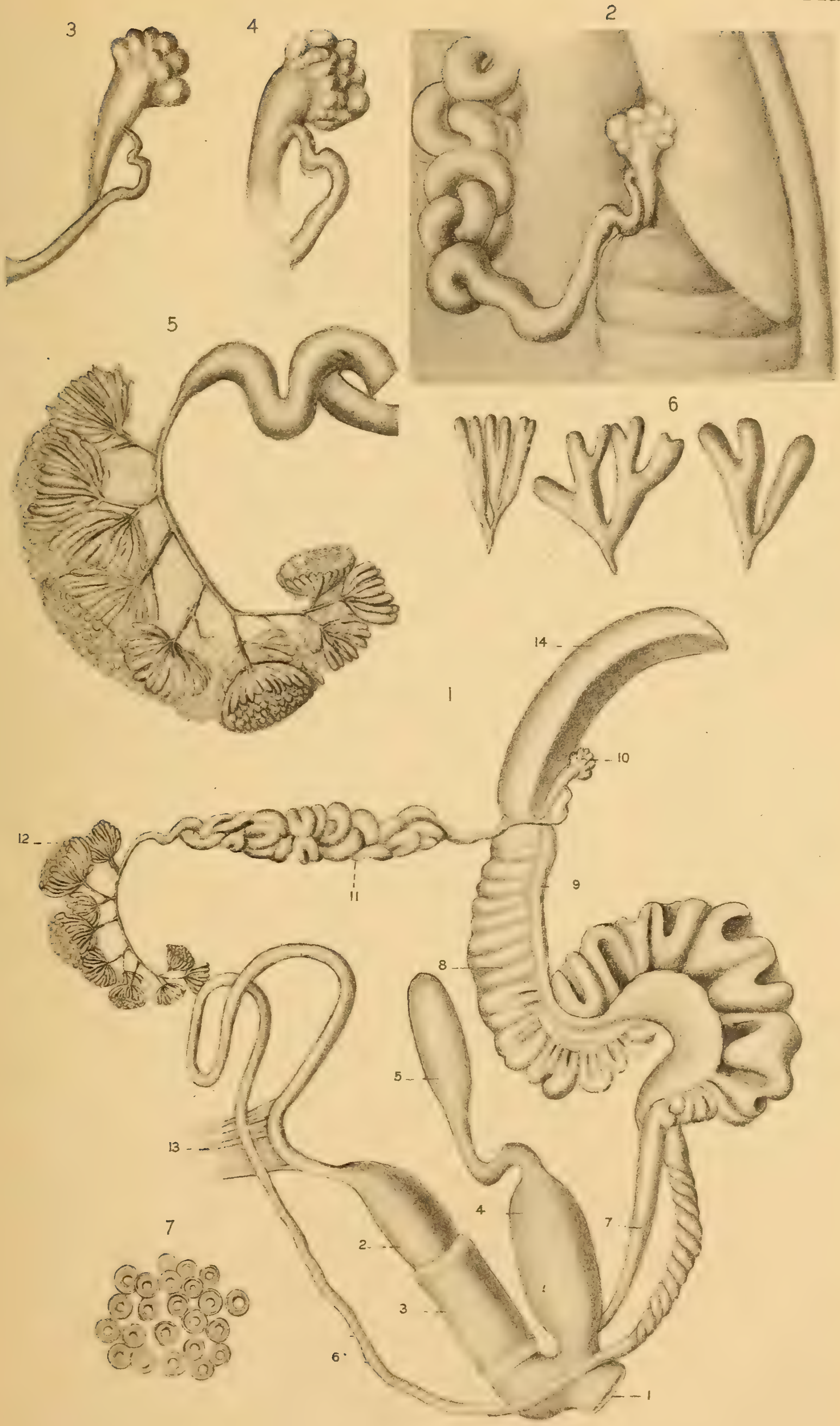

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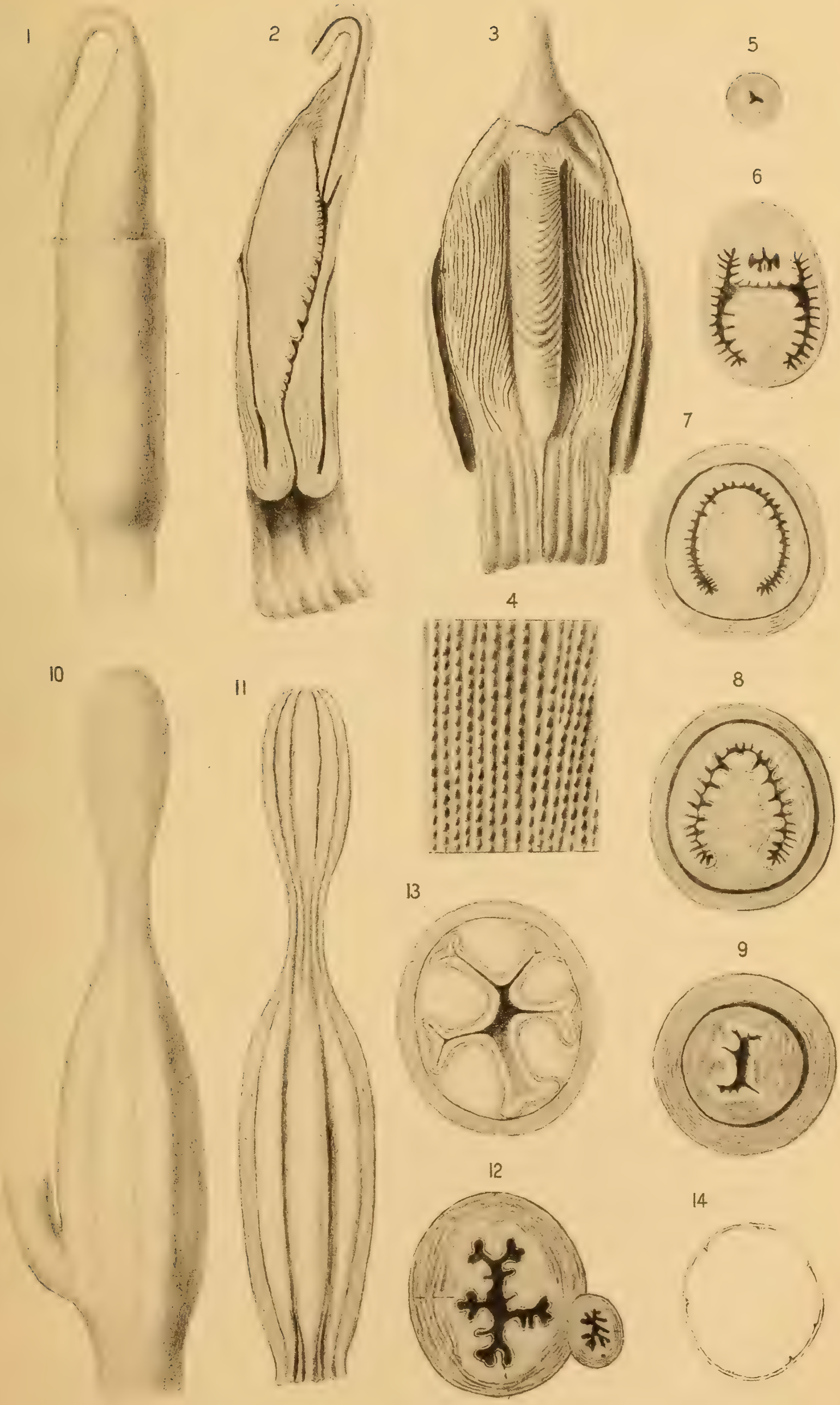

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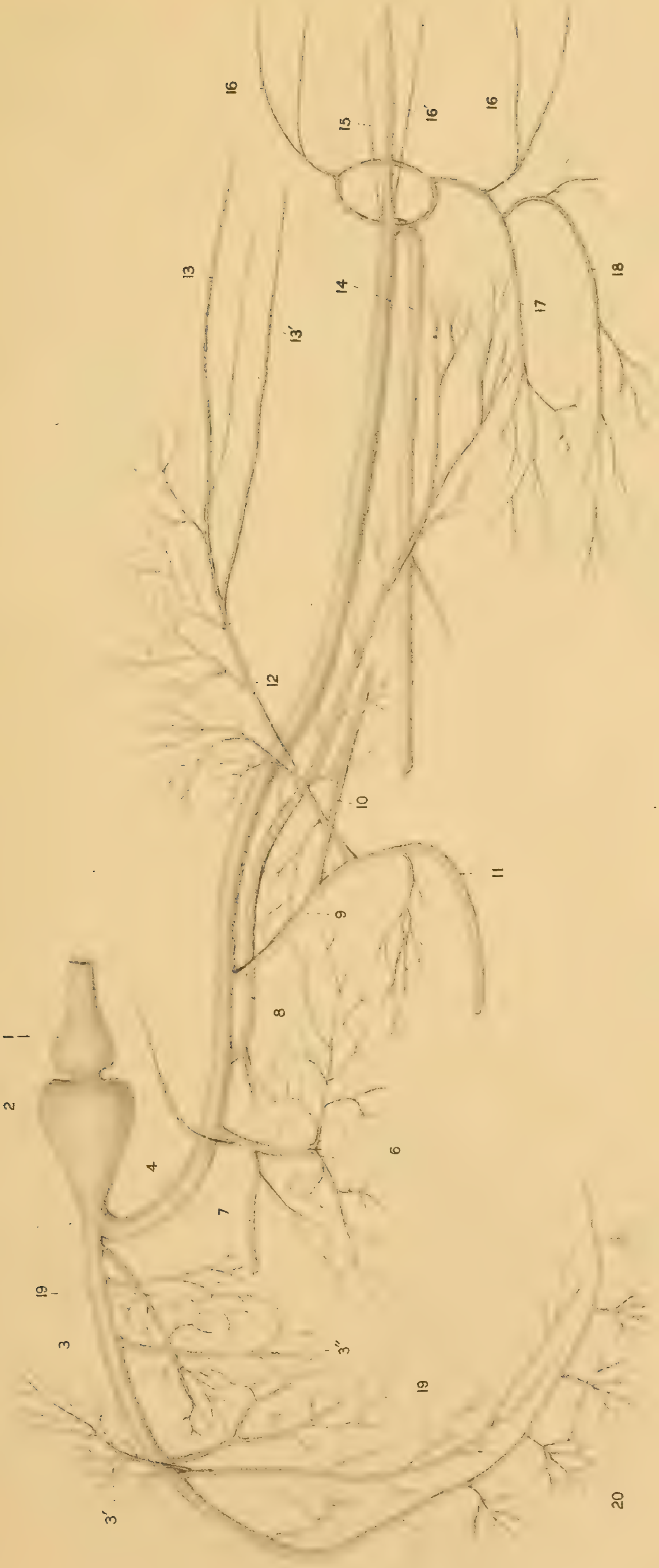

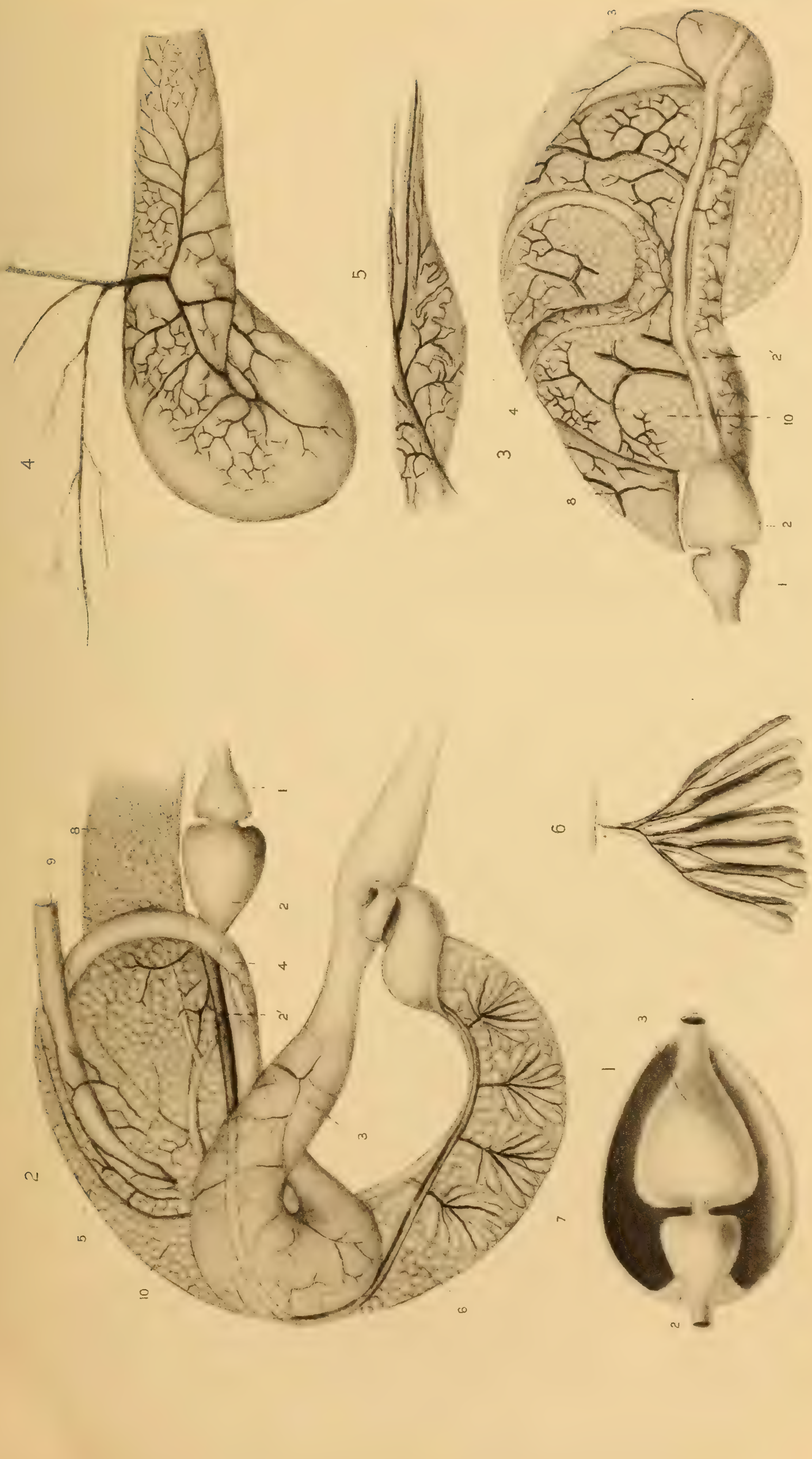

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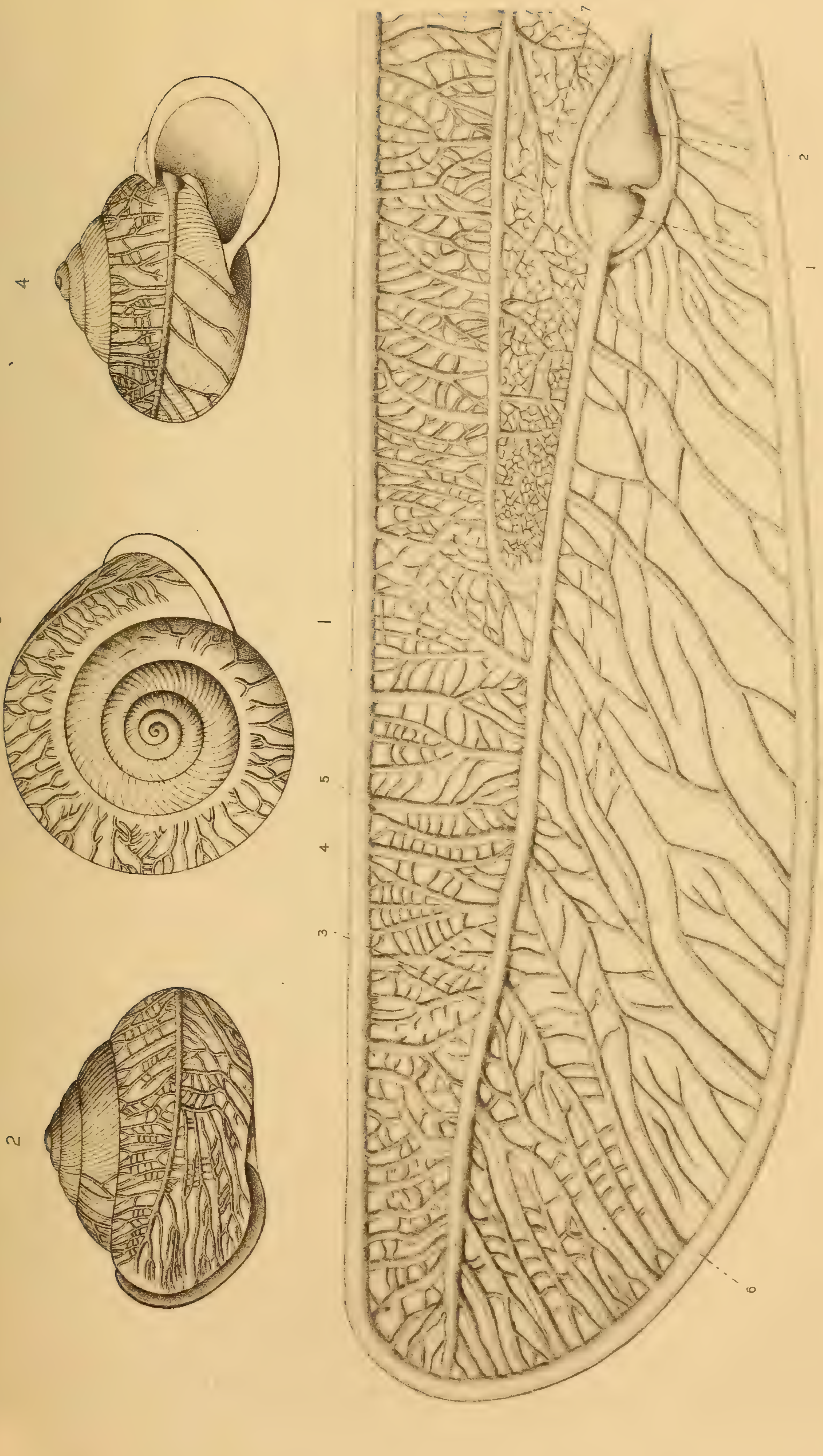

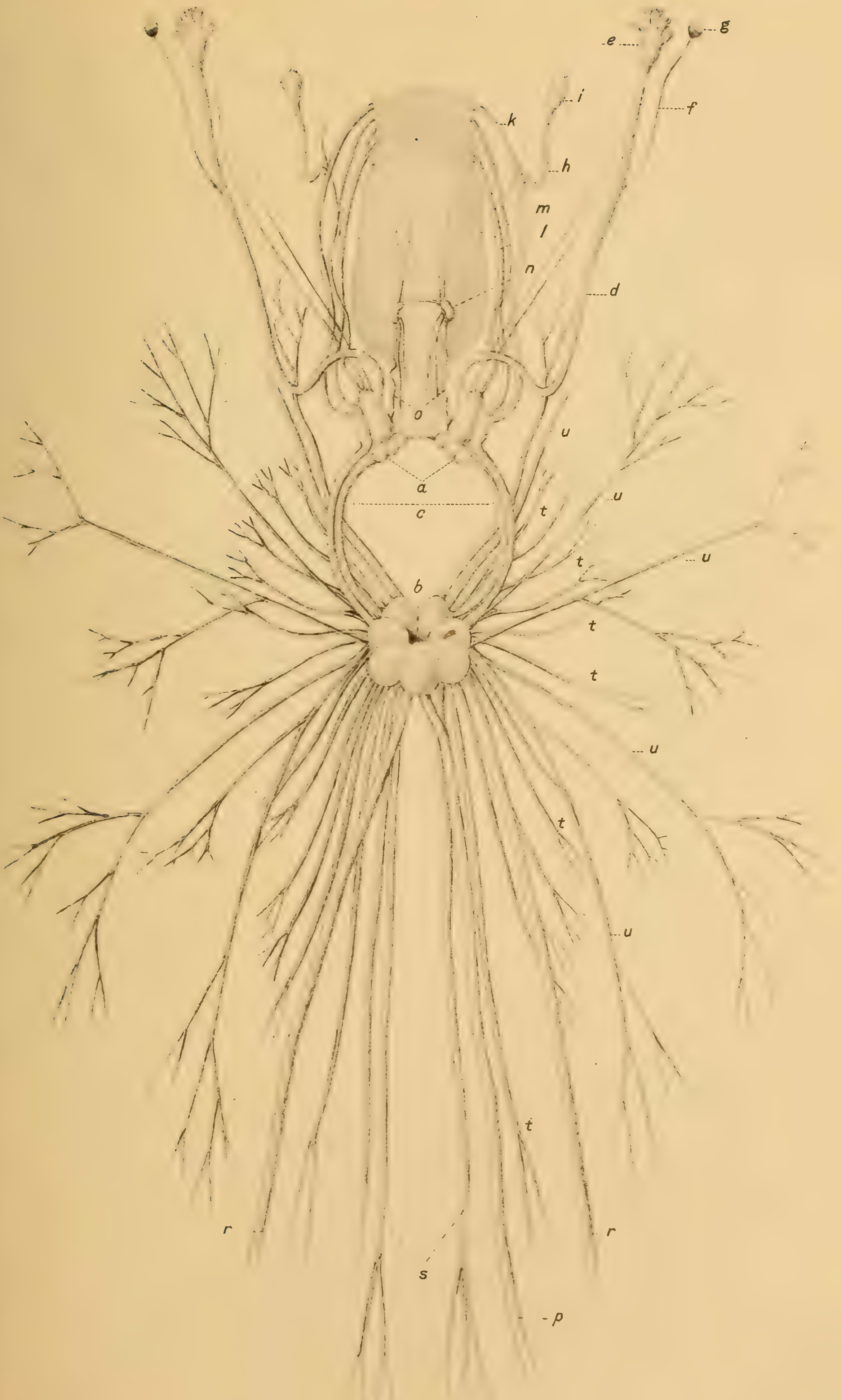
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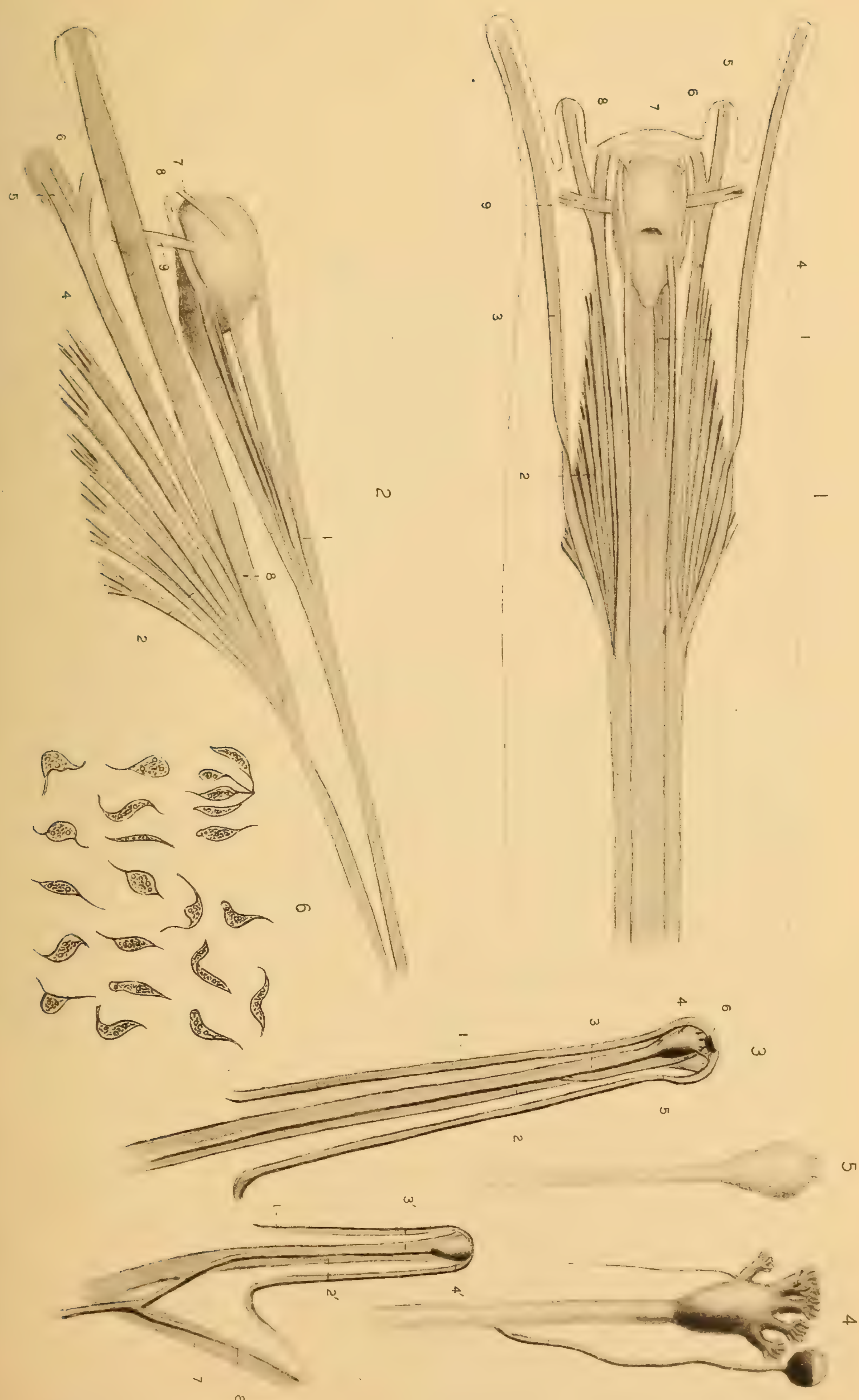


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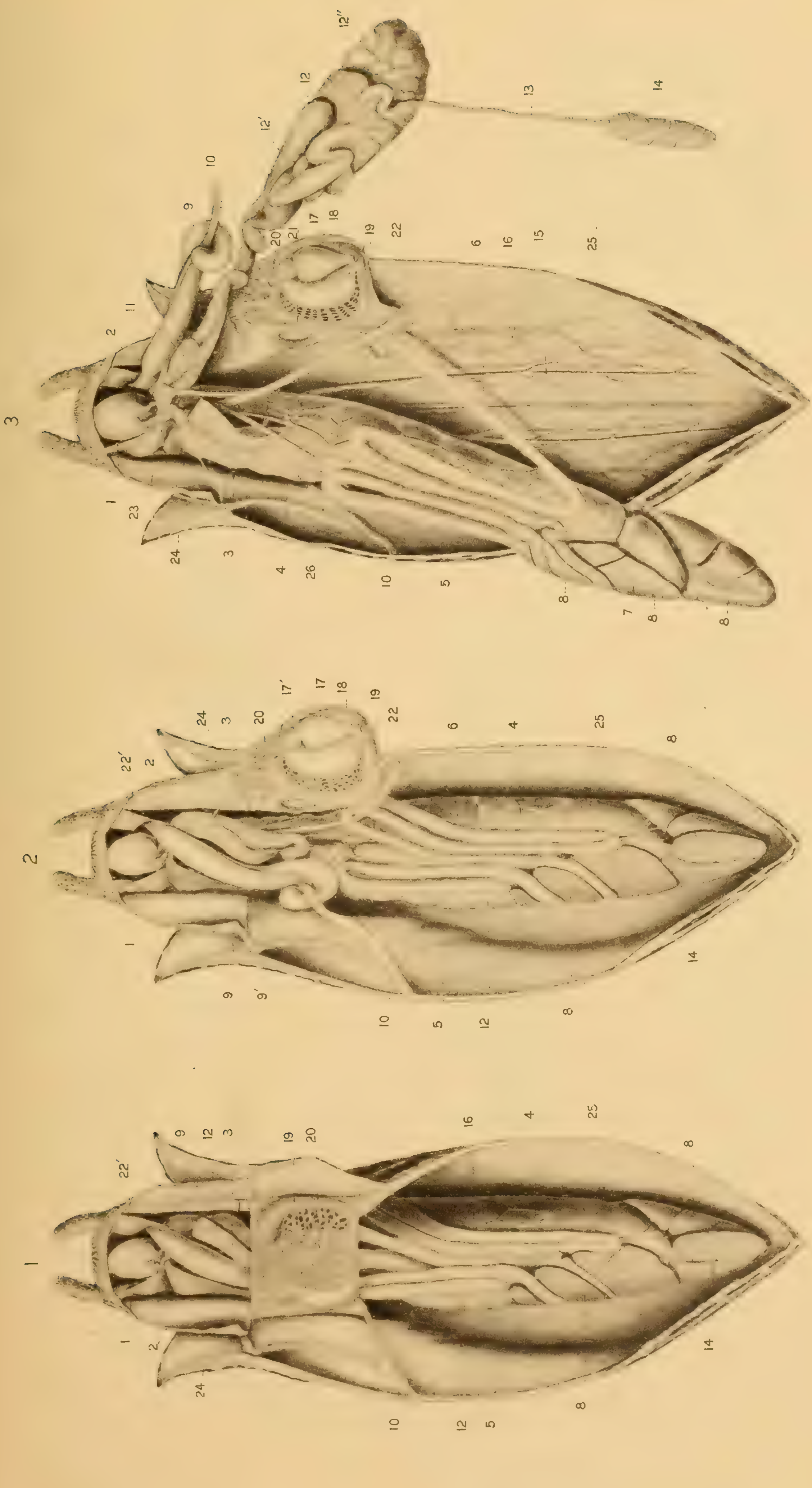

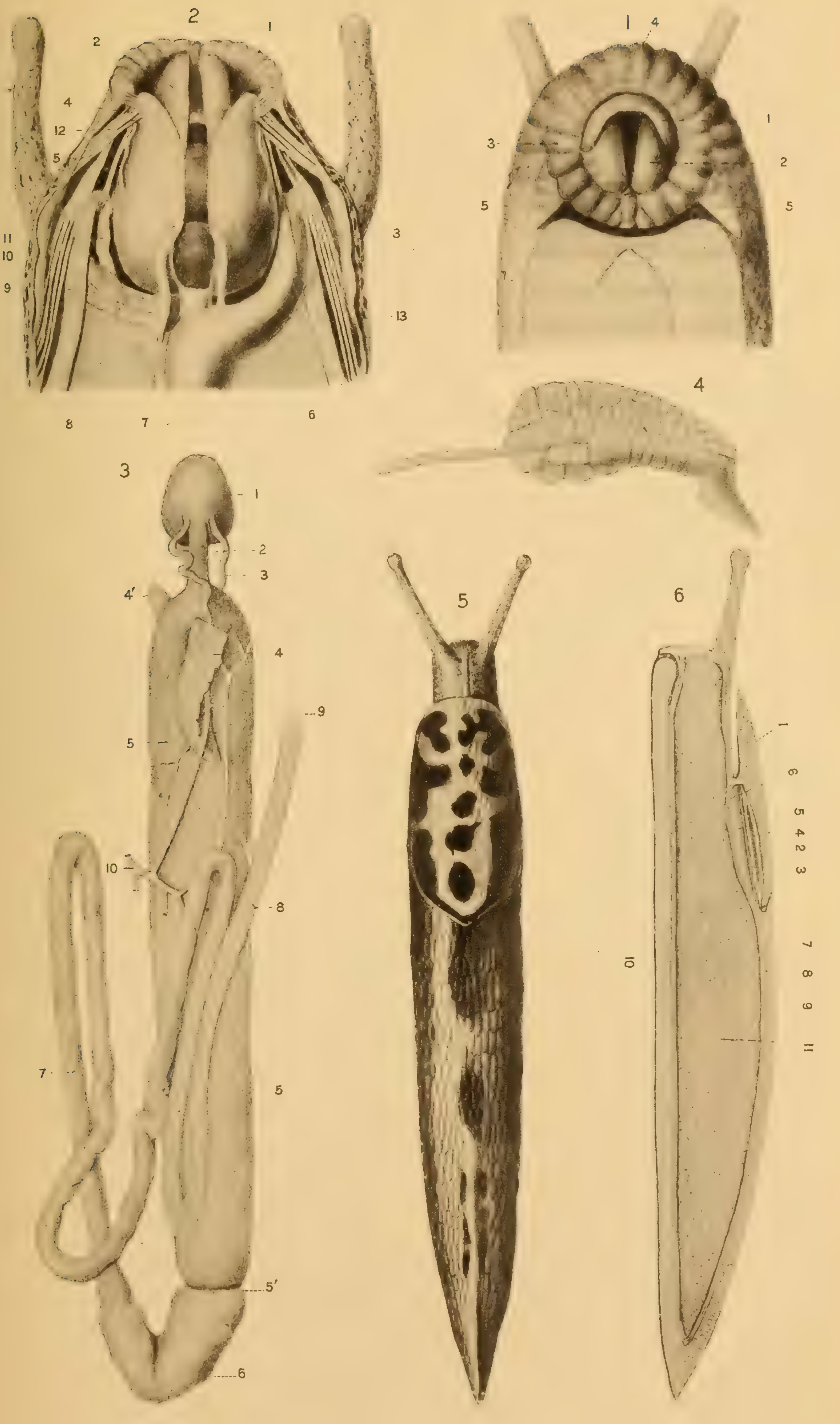

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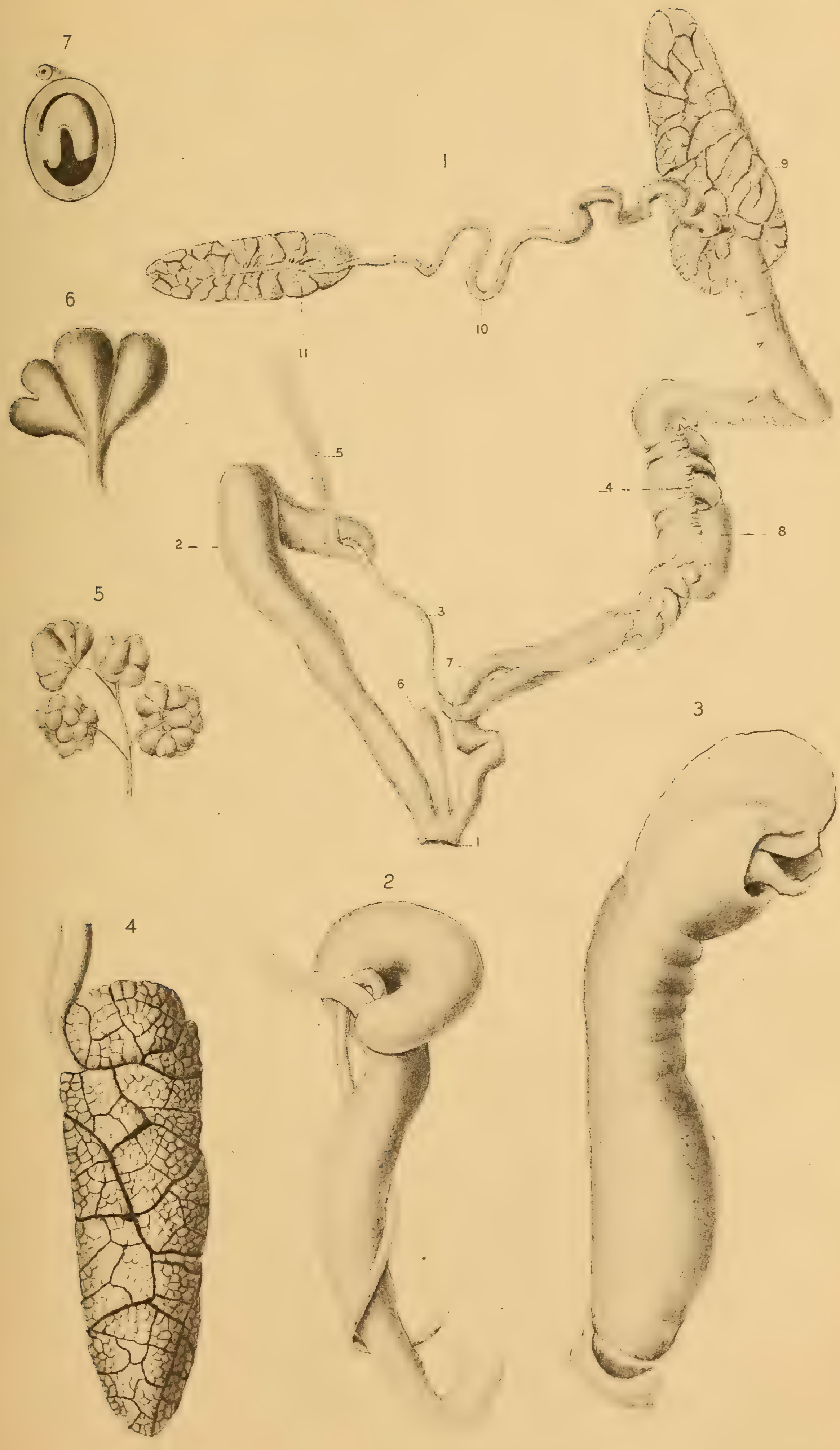

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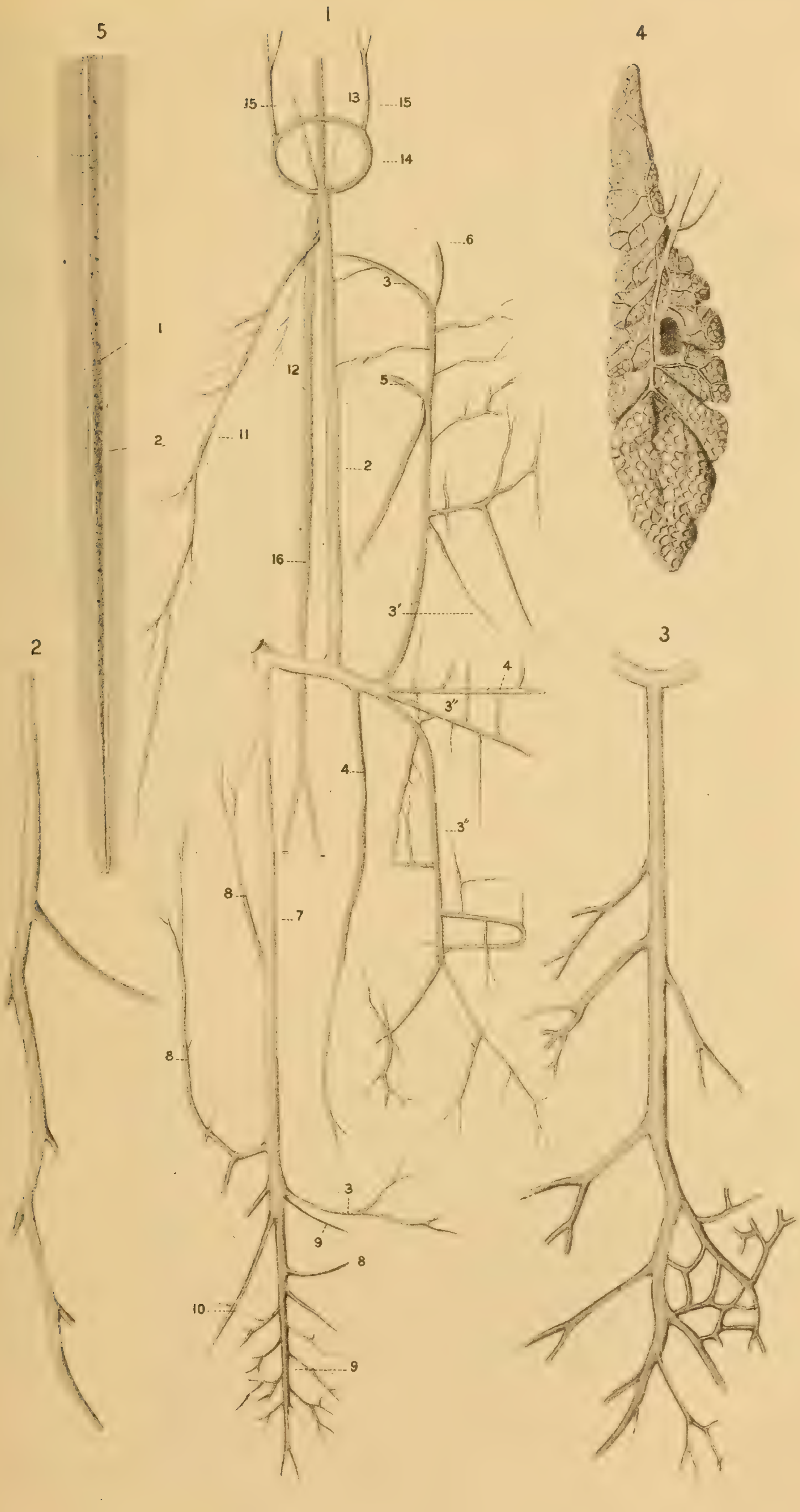

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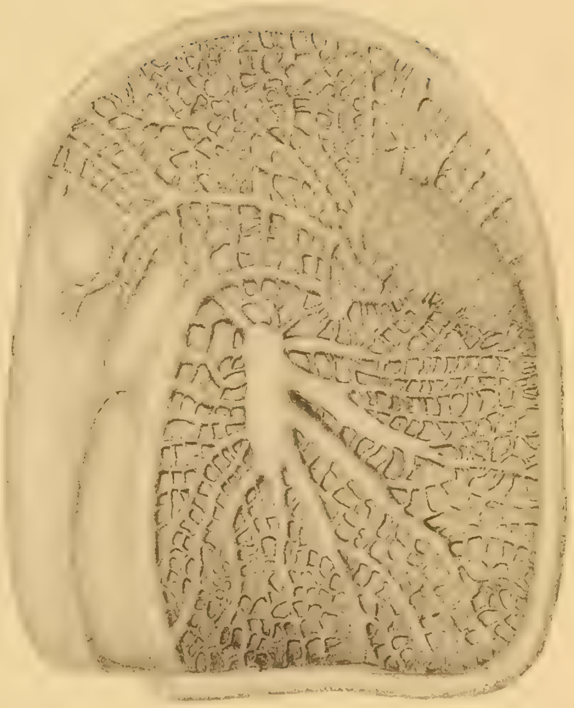

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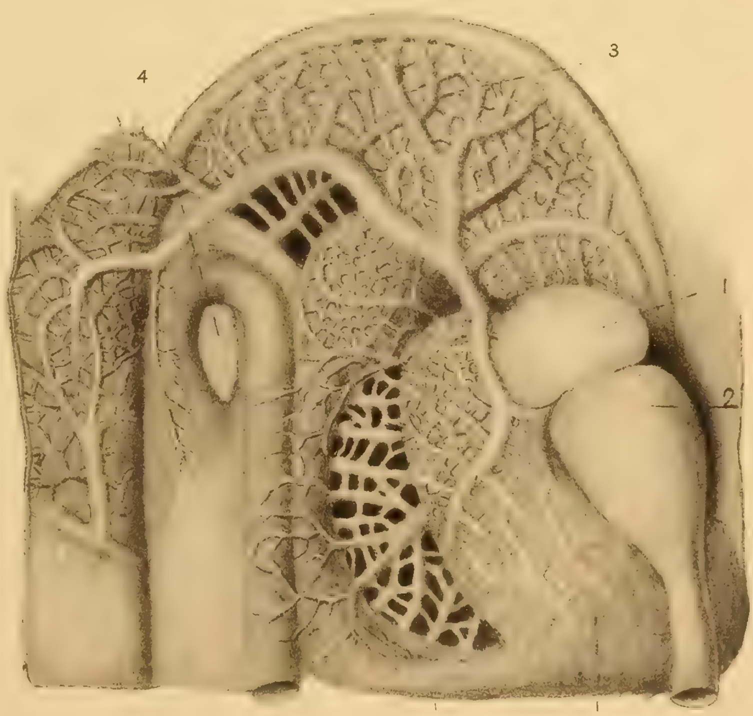

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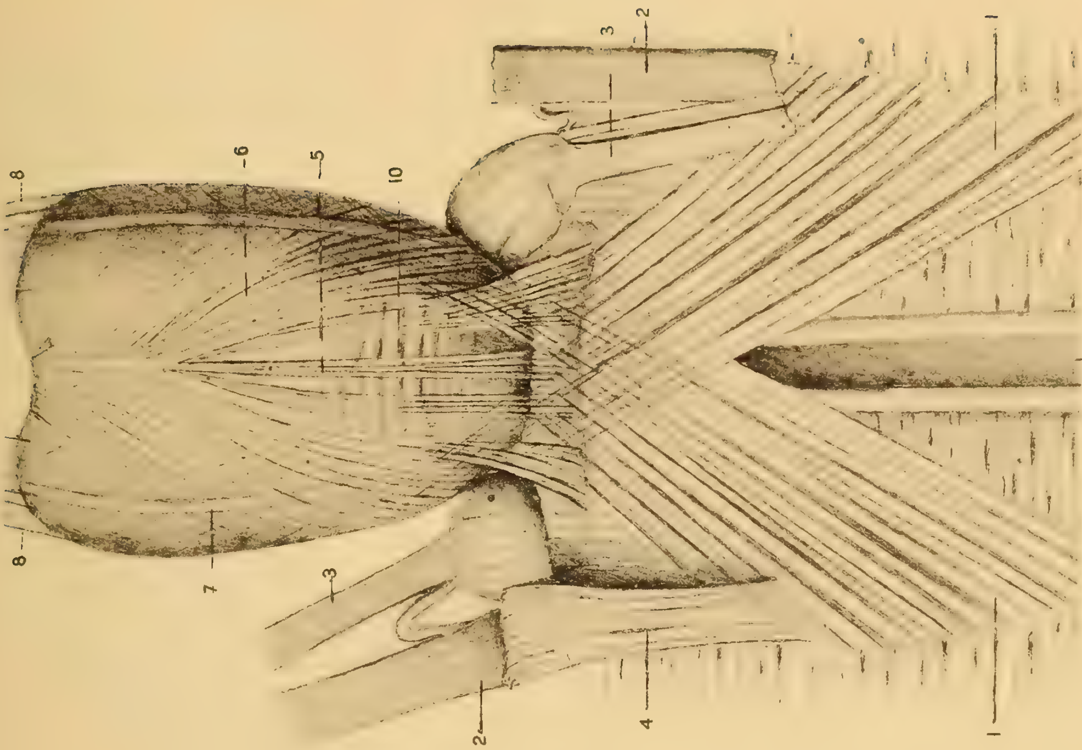

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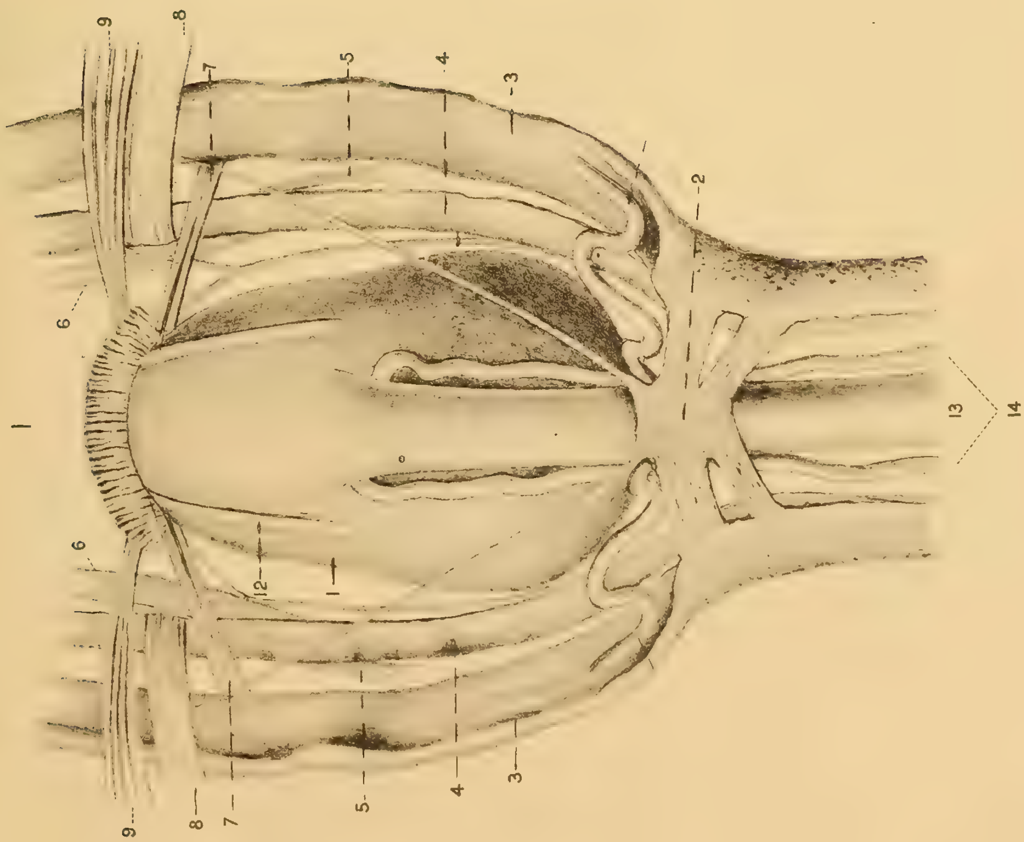

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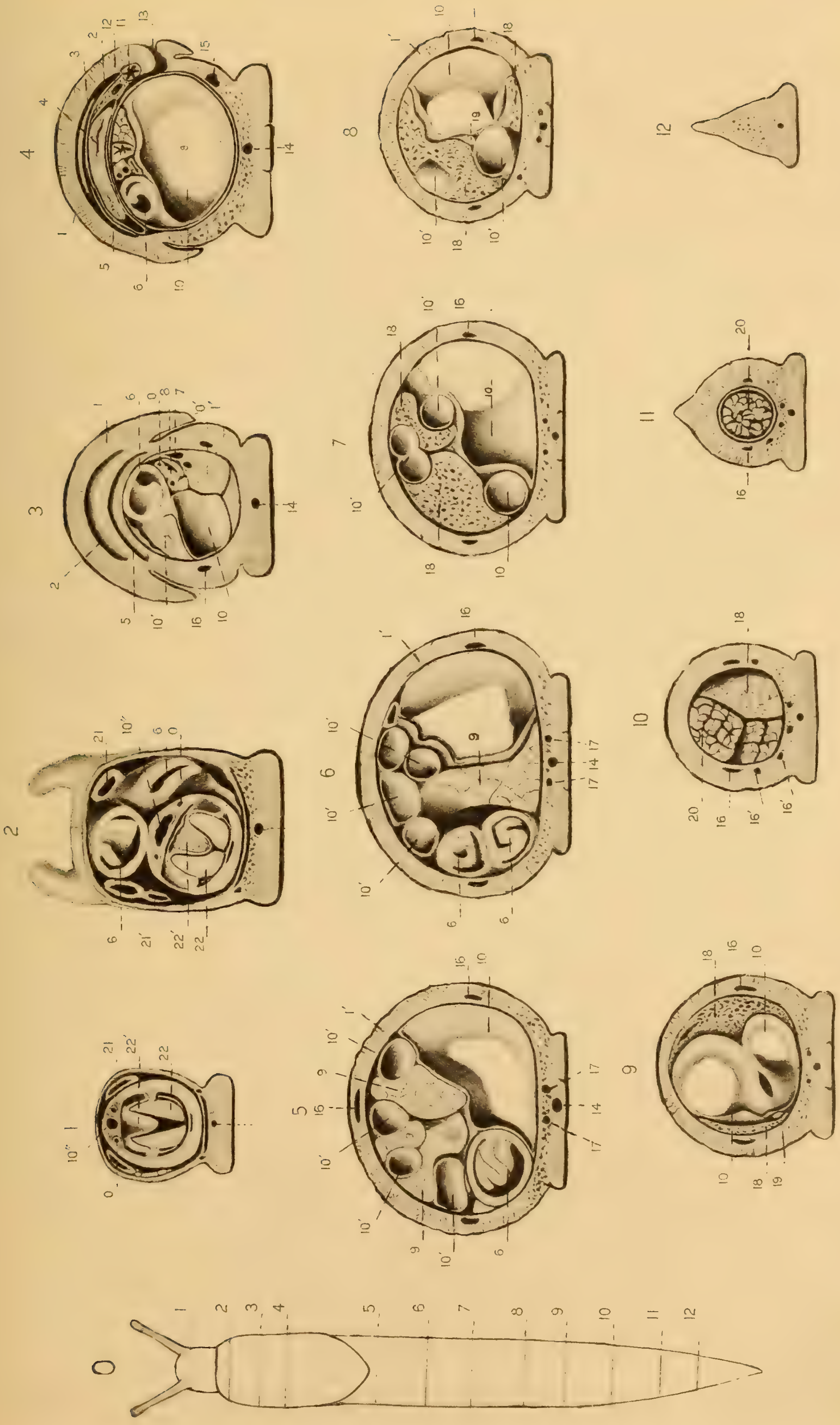

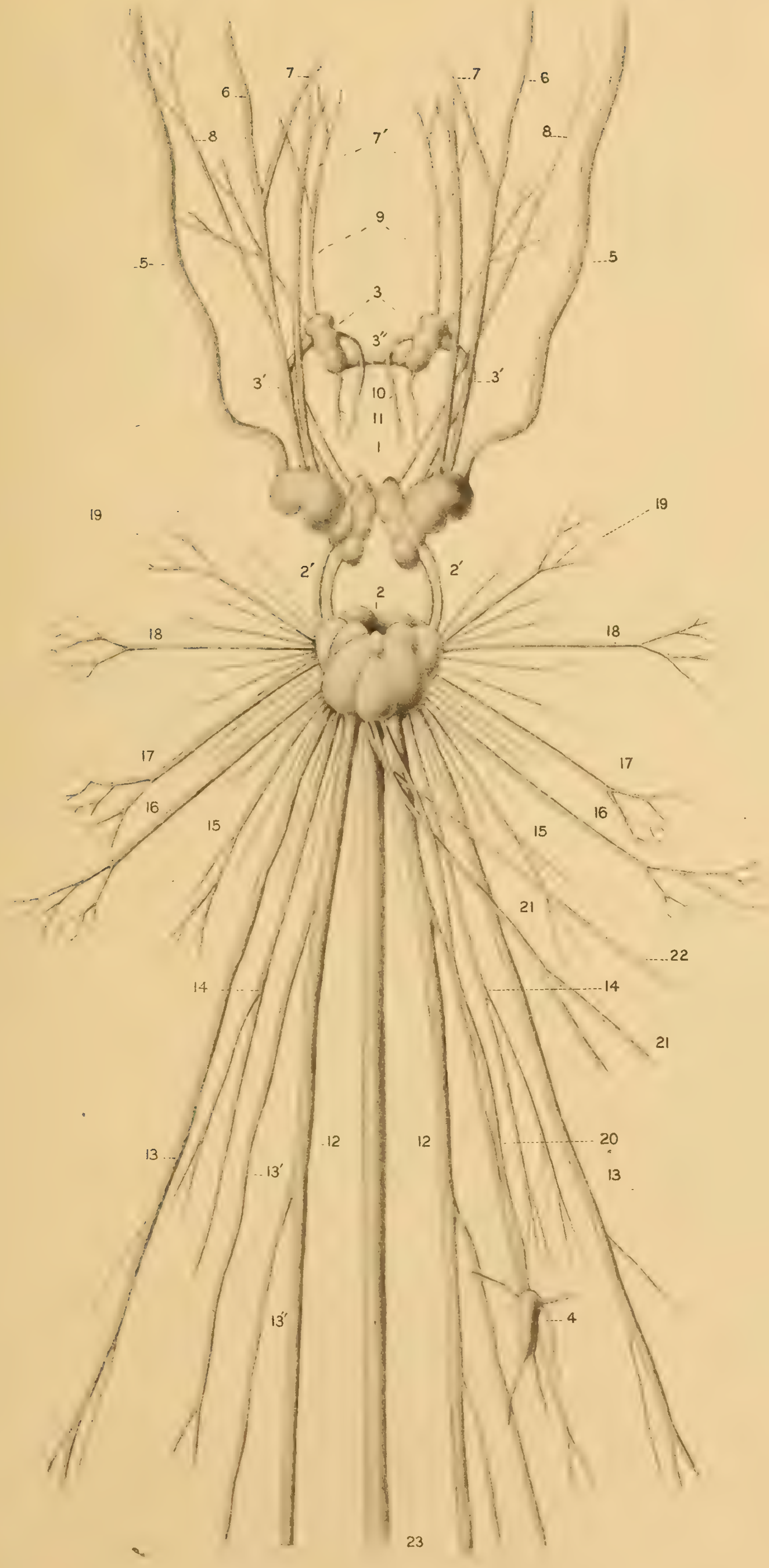
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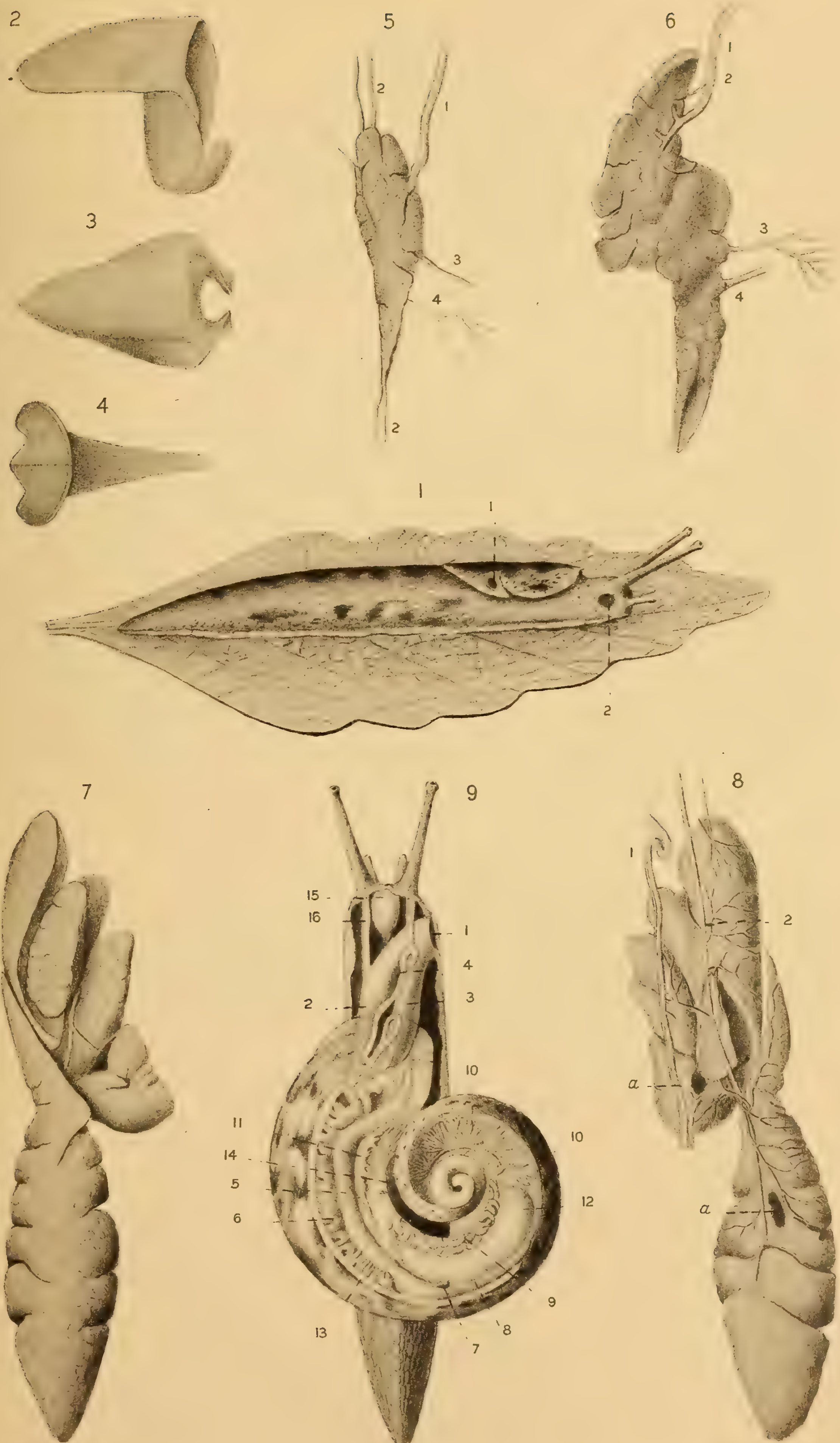

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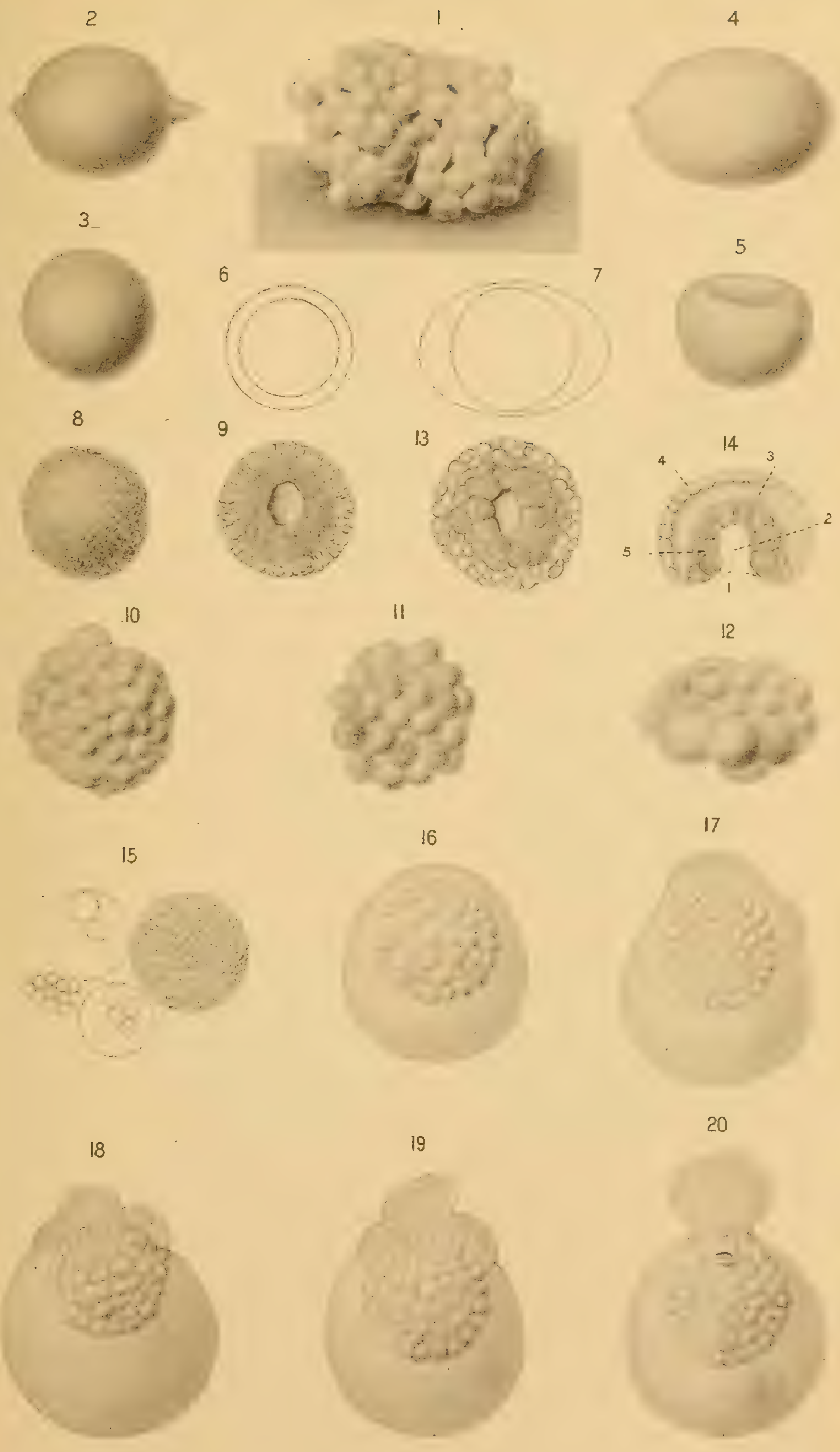

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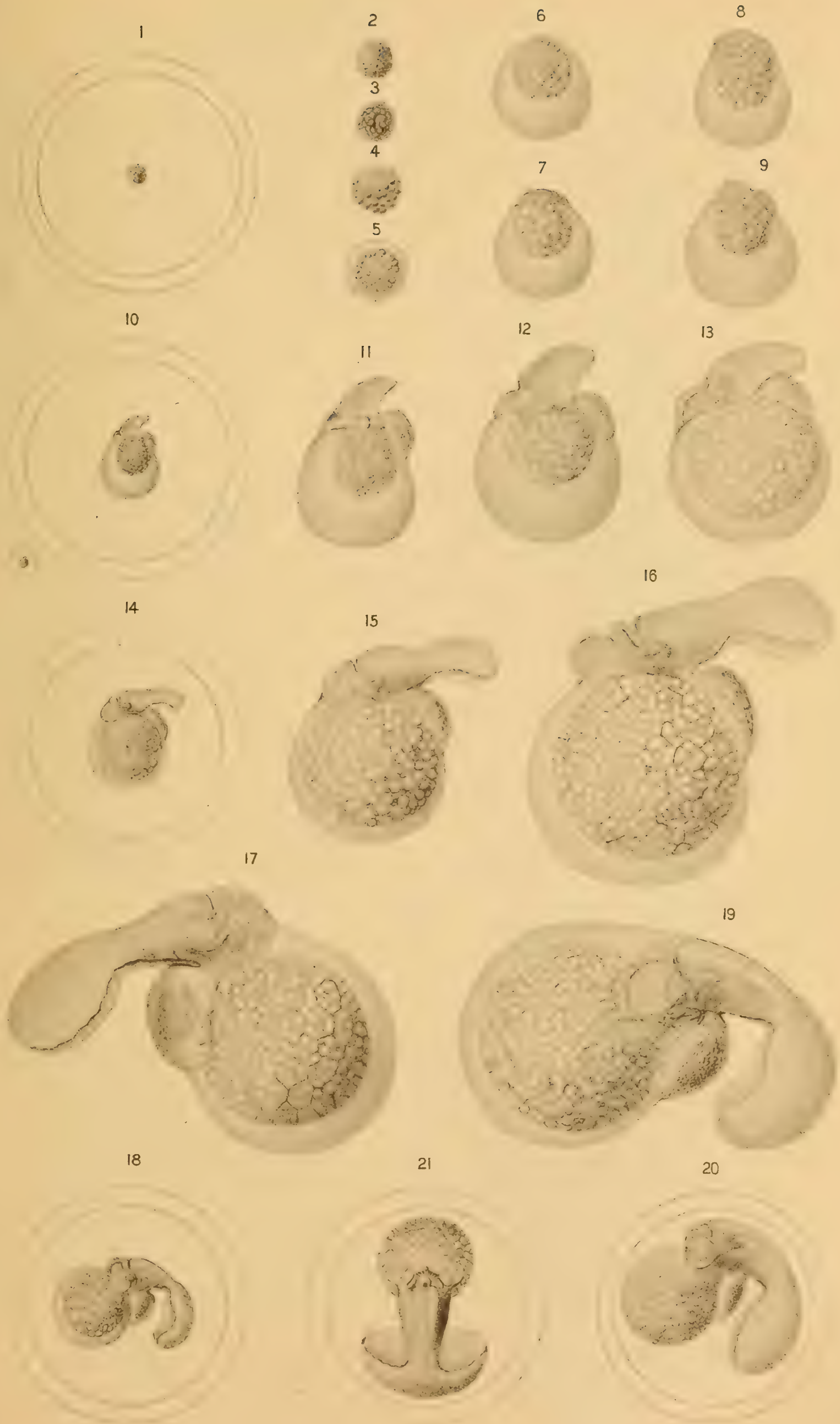

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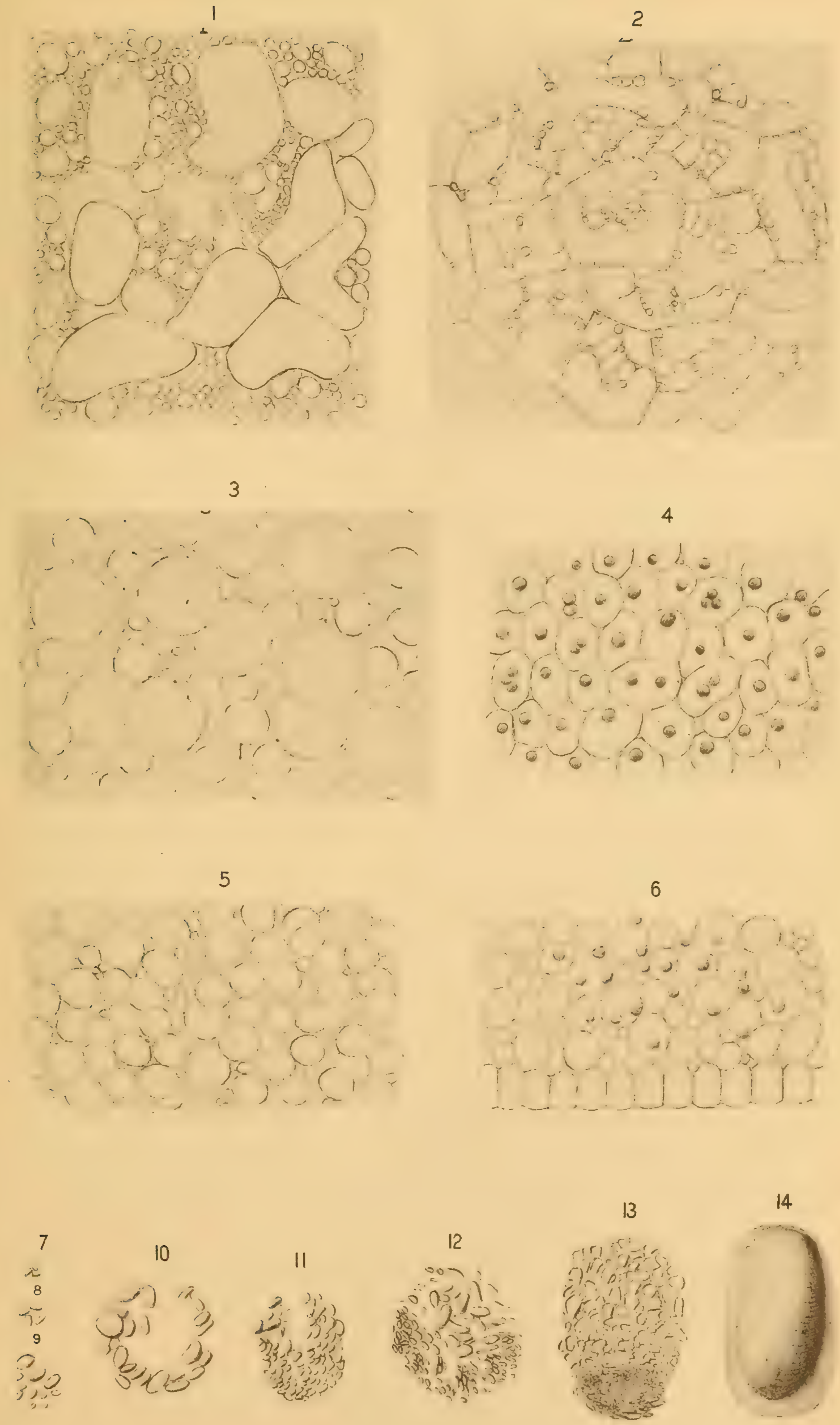
Plate 28



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University of the State of New York

BULLETIN

OF THE

New York State Museum

FREDERICK J. H. MERRILL *Director*

No. 41 Vol. 8

February 1901

WAMPUM AND SHELL ARTICLES

USED BY THE NEW YORK INDIANS

BY

WILLIAM M. BEAUCHAMP S. T. D.

ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
1901

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WAMPUM AND SHELL ARTICLES

Making wampum

The use of shells for ornaments and money is so well known that no discussion of the subject is required here. The aborigines of North America had the common primitive taste, but could not fully gratify it till the white man came. Some shells they were able to work in a simple way, but few of these have been preserved. Under some circumstances they kept well, but they could not withstand much exposure. Pearly shells resisted best, while those in which lime was the principal element soon lost their polish, and often their form.

The aborigines of the Pacific states had the *Dentalium* for money and ornament, but used the iridescent *Haliotis* to a great extent. The Indians of the plains depended mainly on the eastern coast for what they used. A few northern shells were available, but the material for a large proportion of New York articles came from the south Atlantic coast and the Gulf of Mexico. These were most in use in the historic period. Few from the southern coast which are over 300 years old have been found here. Except as beads, shells were little used as ornaments in New York before that time. Yet this state was celebrated for the abundance of its wampum 250 years ago, partly from the stimulus given to its manufacture by the whites, and partly from the numbers and large size of one mollusk, by which it was supplied.

Venus mercenaria is abundant from Cape Cod to Florida, but is rare northward from the former point till the southern shore of the Gulf of St Lawrence is reached. It is the round clam or quahog. It has been objected that the purple part of this shell is not thick enough to make the dark beads. This is true of the clams sent into the interior for food, because the younger mollusks are chosen instead of those old and tough. To correct this impression, W. W. Tooker sent the writer older shells, 4 inches long. Fig. 1 shows one of

these, with the surface distribution of the purple part overlying the white as a rule. Fig. 2 is a section of the posterior part of the shell, where the purple is $\frac{3}{8}$ of an inch thick. At the anterior end it is deposited in bands of purple and white. Fig. 3 is a section of the central basal margin, where the purple is too thin for a good quality of beads. This part was occasionally used, and the shell was cut so as to show the lines of growth. De Kay gives the extreme length as 4.5 inches.

Mr Tooker also furnished some antique columellae from near Sag Harbor, divested of the outer whorls, and thus prepared to be worked into pins or long and short beads. Fig. 4, 5, 6 show three of these, apparently of small shells of Sycotypus canaliculatus. This occurs from Cape Cod to Florida, and is readily recognized by the canal around the spire. Fig. 7 is a young shell of Fulgur carica, often used, and having the same range. It is given here to show the opposite character of Busycon perversum, which was commonly used in the south, not reaching northern shores. The peculiar feature of this latter shell is in having the whorls revolve in the opposite direction to most species, as may be seen. Fig. 8 is from a small specimen in the writer's cabinet. De Kay gave two figures of this shell, revolving in the contrary direction to the typical form, and this without comment. He called it Pyrula spicata, of Lamarck, and said: "I have met with this shell in the collections of Dr Budd and others, but can not find it authenticated as a New York species."—*De Kay*, p. 142. It is not included in the list of invertebrates of Vineyard sound, nor has the writer ever found it on the coast of New York. It is proper to make this statement in correction of what W. H. Holmes has said of locality. "The Busycon perversum has been more extensively used than any other shell, and consequently its distribution in one form or other is very wide. It is obtained along the Atlantic and Gulf coasts from Massachusetts to Mexico, and within the United States it is artificially distributed over the greater part of the Atlantic slope."—*Holmes*, p. 192. Attention is called to its range now, because it is probable that almost all articles made from this north of Maryland are of quite recent use.

The small white council wampum was often made of a smaller gasteropod, or even of the white parts of some bivalves. Fig. 9 is a full size drawing of Buccinum undatum, which is a northern shell, but is found to some extent at Montauk point and elsewhere about Long Island. Beads were made of this. Littorina irrorata is still rarer along the New York coast, but one perforated specimen has been found at the Onondaga fort of 1600, which is shown in fig. 19. Some others will be mentioned later. For ornamental purposes the larger shells were preferred. Mr Tooker says: "Some writers illustrate the basal whorl as being the part from which the wampum was made, but this is contrary to the early writers, who state that it was made 'from the inmost wreaths, stem or stock, when all the shell is broken off.' We find these stems in great abundance about the sites of former wigwams, in shell heaps and other localities." Reference has been made to some figures of these. With all due deference to early writers, it must be confessed that some wrote what they heard rather than what they saw, often quoting largely without the slightest credit or personal knowledge.

At first beads, long or short, were made from the columellae, or pillars of shells, because they could be easily ground before cutting to the desired length, no slight advantage. With better appliances this was less necessary. It is clear, however, that no New York shell was large enough for some beads found here, but after the Iroquois became supreme in power southern material of a massive nature was easily obtained. With the increase of ornaments other parts of the shell became available. The whorls naturally afforded the curves found in gorgets and other things, and it is probable that these articles were first seen by the Iroquois in their southern wars in the 17th century. Sailors brought some materials, and a few articles of Haliotis shell have been found. The gradual increase of shell ornaments may easily be traced in any center of Iroquois occupation, and the use of metallic tools in their production.

In fact these tools changed everything, though there were other reasons for the sudden increase of wampum in the 17th century.

Mr Tooker makes some interesting remarks on the *mucksuck*, or awl blades of Roger Williams. That writer said: "Before they had awl blades from Europe they made shift to bore this their shell money with stones." Mr Tooker comments on this. "Among the articles given for East Hampton town in April 1648, to the Montauk Indians were 'one hundred *muxes*.' In the Indian deed for Huntington, L. I., dated 1653, are mentioned '30 *muxes*, 30 needles.' In the Indian deed for Mastic Neck, Brookhaven, L. I., dated 1657, among the items paid to Wyandance, sachem of Montauk, were 'forty needles and forty *muxes*.' So it will be seen that they were articles highly desired by the natives."

It is quite probable that these awls were made with a view to the Indian trade, and thus acquired a name common among them. If specially adapted for this work, their value would be proportionally increased in making and selling, and the name would distinguish them. Still the work would be slow and laborious, and not adapted to the small cylinders of the council wampum, making it probable that the Dutch soon produced all of this variety, leaving to the Indians the larger and more showy kinds.

Thompson says, in his *History of Long Island*, p. 61, that "Hazard, in his collection of state papers, mentions that the Narragansetts procured many shells from Long Island, out of which they manufactured Indian money, and that they likewise frequently compelled the natives of the island to pay them large tribute in money." In John Winthrop's *Journal*, 1:112, is mentioned the return of his bark, *Blessing*, Oct. 2, 1633, from Long Island. "There they had store of the best wampum peak, both white and blue." It seems probable that not only was the material unusually fine there, but the Indian makers obtained iron tools at a very early day.

A quotation from Van der Donck, in 1653, will show how much faster work the Indians themselves did when furnished with these tools. They "drill a hole through every piece, and string the same on strings, and afterwards sell their strings in that manner. . . Many thousand strings are exchanged every year near the seashore, where the wampum is only made, and where the peltries are brought for sale." Though the number of beads and strings is indefinite,

it is implied that it was very large. From slight experiments in drilling the writer finds it less difficult than is sometimes represented.

Roger Williams gave the words, *puckwhéganash* and *mucksuck* for the awl blades already mentioned. It may be observed, also, that the word *muges* is used in the printed record of the deed of East Hampton, in 1648, instead of *muxes*, as given by Mr Tooker. In the *Documentary history of the state of New York* it is *mucxs*, which is nearer his rendering. In the same deed the Indians "reserve libertie to fish in all convenient places, for Shells to make wampum."—*Rec. East Hampton*, 1 :3. Evidently the trade was highly valued by them.

Unio beads and ornaments are very rare, considering how fine and abundant was this material, and but two other genera of fresh-water shells appear in use. Some marine species will be mentioned in treating of articles, but Melampus bidentatus was occasionally used in early and recent times. It is neither showy nor durable, but is of the desired form, requiring merely perforation.

The manufacture of articles of shell was at first mainly on or near the seashore. Unio beads are very rarely found in the interior of New York, and the writer has noticed a few perforated Goniobasis and Melantho shells not otherwise worked. All these are fresh-water species, and the last may have been earliest in use. This perforated green shell has been found sparingly in Erie and Jefferson counties, and may occur elsewhere. Fig. 17 and 18 show some from the former county, perforated near the lip, as in all other cases. Goniobasis is a smaller and more slender shell, and perforated specimens of two species occur from Madison county westward. Schoolcraft described one as a Marginella. Fig. 25 shows some from the fort west of Cazenovia. Quite a number have been found there, and they are about 300 years old. They do not occur naturally within 20 miles of the spot. A few have been found in the country of the Senecas, mostly from recent sites in Livingston county, and they seem to be the fresh-water shell beads of Seneca tradition.

Long shell beads are sometimes found in the interior, possibly

of early date. The finest are from the east side of Cayuga lake, and they vary from nearly 7 inches in length to those quite short. Fig. 121 represents one of these. Small perforated seashells are found on recent sites, and were used as beads. Fig. 20, 22, 26 and 30 show some out of several varieties. Fig. 19 is Littorina irrorata, a Long Island shell, found at the fort west of Cazenovia. It is rare north of Maryland.

Gardiners bay and the east end of Long Island were the original seat of the wampum trade in New York, less ancient than has been supposed, and thence it reached the New England coast in recent times. An early writer said that the Narragansetts "were the most curious coiners of the wampumpeag, and supplied the other nations with many pendants and bracelets." Roger Williams's account is quoted elsewhere. Adriaen Van der Donck said that the black wampum was prepared from conch shells cast ashore twice a year. The Indians preserved the pillars of these, ground and drilled them. He erred in the species. Daniel Denton wrote a *Brief description of New York* in 1670, which was reprinted in 1845. A note in this says that the best wampum was made of the hearts of the common hard clam on Long Island, and was sent to the western Indians for money and council purposes. "The Indians broke off about half an inch of the purple color of the inside, and converted it into beads. These, before the introduction of awls and threads, were bored with sharp stones, and strung upon sinews of animals, and when interwoven to the breadth of the hand, more or less, were called a belt of seawant or wampum. A black bead, of the size of a large straw, about half an inch long, bored lengthwise and well polished, was the gold of the Indians and always esteemed of twice the value of the white. . . Seawant was also sometimes made from the common oyster shell, and both kinds were made from the hard clam shell.—*Denton*, p. 41-42

The writer often finds the white beads made from the columella of small spiral shells. Roger Williams said of the Indians: "Most on the Sea side make Money, and Store up shells in Summer against Winter, whereof to make their money."

In his *History of Long Island*, Thompson says: "The immense quantity that was manufactured accounts for the fact that, in the

most extensive shell banks left by the Indians, it is rare to find a whole shell, all having been broken in the process of making wampum. And it is not unlikely that many of the largest heaps of shells still existing are the remains of a wampum manufactory." In an address at Brooklyn in 1892, Mr Tooker did not take so extreme a view. Of the shell heaps he said: "They are all true kitchen middens, and in them can be found nearly everything not perishable that was used by the red men. . . Many of the shells found bear marks of the wampum maker. The spirals of the periwinkle (Pyrula canaliculata) are very common, this part of the shell having been used to produce the white beads or true wampum. I have found these shells buried in a mound by themselves in several localities, to the extent of a bushel or more, this being done in order that the fish might decay and leave the shells more easy to work."

Loskiel has some notes on early wampum.

Before the Europeans came to North America the Indians used to make their strings of wampum chiefly of small pieces of wood of equal size, stained with black or white. Few were made of mussels, which were esteemed very valuable and difficult to make; for, not having proper tools, they spent much time in finishing them, and yet their work had a clumsy appearance. But the Europeans soon contrived to make strings of wampum, both neat and elegant, in abundance. These they bartered with the Indians for other goods, and found this traffic very advantageous. The Indians immediately gave up the use of the old wooden substitutes for wampum and procured those made of mussels, which, though fallen in price, were always accounted valuable. . . Formerly they used to give sanction to their treaties by delivering a wing of some large bird, and this custom still prevails among the more western nations in transacting business with the Delawares. But the Delawares themselves, the Iroquois, and those nations in league with them, are now sufficiently provided with handsome and well wrought strings and belts of wampum.—*Loskiel*, p. 26

He gave a good account of its making and use.

The most elaborate account of its recent manufacture may be found in Barber and Howe's *Historical collections of the state of New Jersey*, under the head of Bergen county, published in 1844.

Wampum, or Indian money, is to the present day made in this county and sold to the Indian traders of the far west. It

has been manufactured by the females in this region from very early times for the Indians. . . The wampum is made from the thick and blue parts of sea clamshells. The process is simple, but requires a skill only attained by long practice. The intense hardness and brittleness of the material render it impossible to produce the article by machinery alone. It is done by wearing and grinding the shell. The first process is to split off the thin part with a light sharp hammer. Then it is clamped in the sawed crevice of a slender stick, held in an eight sided figure of about an inch in length and nearly half an inch in diameter, when it is ready for boring. The shell then is inserted into another piece of wood sawed similarly to that above, but fastened firmly to a bench of the size of a common stand. One part of the wood projects over the bench, at the end of which hangs a weight, causing the sawed orifice to close firmly upon the shell inserted on its under side, and to hold it firmly, as in a vice, ready for drilling. The drill is made from an untempered handsaw. The operator grinds the drill to a proper shape, and tempers it in the flame of a candle. A rude ring, with a groove on its circumference, is put on it, around which the operator (seated in front of the fastened shell) curls the string of a common hand-bow. The boring commences by nicely adjusting the point of the drill to the center of the shell, while the other end is braced against a steel plate on the breast of the operator. About every other sweep of the bow the drill is dexterously drawn out, cleaned of the shelly particles by the thumb and finger, above which drops of water from a vessel fall down and cool the drill, which is still kept revolving by the use of the bow with the other hand, the same as though it were in the shell. This operation of boring is the most difficult of all, the peculiar motion of the drill rendering it hard for the breast. . . Peculiar care is observed lest the shell should burst from heat caused by friction. When bored half way the wampum is reversed and the same operation repeated. The next process is the finishing. A wire about 12 inches long is fastened at one end to a bench. Under and parallel to this wire is a grindstone fluted on its circumference, hung a little out of the center so as to be turned by a treadle moved with the feet. The left hand grasps the end of the wire, on which are strung the wampum, and as it were wraps the beads around the hollow or fluted circumference of the grindstone. While the grindstone is revolving the beads are held down on to it, and turned round by a flat piece of wood held in the right hand, and by the grinding soon become round and smooth. They are then strung on hempen strings about a foot in length. From five to 10 strings are a day's work for a female. They are sold to the country merchants for 12½ cents a string, always command cash, and constitute the support of many poor and worthy families.—*Barber*, p. 72-73

It will be observed that these beads are about four times the length of the belt wampum, but the process is the same. The steel drill made a nearly uniform hole; that of the early Indian tapered to the center from each end, his tools being simpler. Other briefer accounts might be quoted. In 1831 several bushels were brought from Babylon on Long Island for western traders, and in 1850 the best for this purpose was still manufactured there. In his *Pictorial field-book of the revolution*, 1:302, B. J. Lossing said: "A considerable quantity of wampum is manufactured at the present time in Bergen county, New Jersey." This continued for a score of years longer. The writer has observed that a great deal of the purple belt wampum is quite angular. Its manufacture by the whites has been noted by many, and several families in Albany long obtained a living by it.

Catlin made some remarks on wampum which may not be entirely correct. He said it was made "by the Indians from varicolored shells which they get on the shores of fresh-water streams, and file or cut into bits of half an inch or an inch in length, and perforate (giving to them the shape of pieces of broken pipestems), which they string on deer's sinews, and wear on their necks in profusion, or weave them ingeniously into warbelts for the waist." His farther words are of interest:

It is a remarkable fact, and worthy of observation in this place, that after I passed the Mississippi I saw but very little wampum used; and on ascending the Missouri (1832) I do not recollect to have seen it worn at all by the upper Missouri Indians, although the same materials for its manufacture are found in abundance through those regions. I met with but very few strings of it amongst the Missouri Sioux, and nothing of it amongst the tribes north and west of them. Below the Sioux, and along the whole of our western frontier, the different tribes are found loaded and beautifully ornamented with it, which they can now afford to do, for they consider it of little value, as the fur traders have ingeniously introduced a spurious imitation of it, manufactured by steam or otherwise, of porcelain or some composition closely resembling it, with which they have flooded the whole Indian country, and sold at so reduced a price as to cheapen and consequently destroy the value and meaning of the original wampum, a string of which can now but very rarely be found in any part of the country.—*Catlin*, 1:222-23

At that very time true wampum was largely made on Long Island and in New Jersey for the western trade. It was counterfeited at a very early day. His statement about fresh-water shell beads has little foundation.

A very early account of North American shell beads will be found in Lescarbot's *Histoire de la Nouvelle-France*, 1609, v. 6, ch. 12, in which he speaks of the Micmacs. He says:

The Brazilians, Floridians and Armouchiquois make carcanets and bracelets (called *bou-re* in Brazil and *matachiaz* by our Indians), from the shells of those great seashells which are called *vignols* and are like unto snails, which they break in a thousand pieces and gather up, then polish them upon a grindstone, so that they make them very small, and when they have pierced them they make beads, like those which we call porcelain. Among these beads mingle alternately other beads, as black as the others I have spoken of are white, made of jet or of certain hard or black woods which resemble it, which they polish and make as small as they wish, and this has a good grace. . . These collars, scarfs and bracelets of *vignols*, or porcelain, are more valuable than pearls (notwithstanding no one will believe me in this), for they esteem them more than pearl, gold or silver. As with us, so in this land do the women deck themselves with such things, and will make a dozen turns of it around the neck, hanging upon the breast, and around the wrists and below the elbow. They also hang long chains in their ears, which hang down even as low as their shoulders.

Large shells were not found so far north, and they prized those of the Armouchiquois, or Kennebec Indians, but on account of the war the French supplied "little tubes of glass mixed with tin or lead, which are traded to them by the fathom measure for want of an ell measure."

Early shell beads

In S. L. Frey's article entitled "Were they mound-builders?" *American naturalist*, 1879, p. 637-44, are good descriptions of the shell articles he found in the stone graves at Palatine Bridge. In the first examined he found "a seashell, somewhat modified for a drinking vessel, its longest diameter being 4 inches." Fig. 43 is from his drawing of this cup. This grave had a stone tube. In another, containing two tubes, he found a necklace of shell and copper beads. "Many of the shell beads were also stained by copper;

those so colored retaining their original polish, being hard and glossy like ivory, while those not so stained were brittle, many of them falling into a white, laminated powder. The shell beads were 59 in number, besides those that were too badly decayed to handle, and were from half an inch to one and three quarter inches in length, and averaged about half an inch in diameter. They were of that kind so fully described by the early writers, made from the columellae of large seashells and rubbed and ground smooth with great labor, and afterward drilled through their longest diameter with greater labor still. . . The drilling has been done in most cases from each end, the holes meeting in the center. In some of the shorter ones, however, the perforations were made from one end, being of uniform size throughout. The spiral grooves, where the whorls of the shell wound round the hard central column, can be seen in all of them."

In another grave, lined with flat stones, he found "little copper tubes and small seashells about half an inch long, with a hole drilled in the large end. The only way that these latter can be strung is with a 'waxed end' tipped with a bristle, such as shoemakers use. This follows the whorls of the shell." The writer makes full quotations here because these may be the oldest shell beads yet found in New York. They were in peculiar graves and associated with articles very different from those of more recent times, though themselves of precisely the same character as later beads. Mr Frey is so well known as a careful, experienced and intelligent observer, that it is always a pleasure to quote from him. In a recent letter to the writer he refers to these articles. "I found at the same time about 75 beads from half an inch long to 2 inches. They were in fine condition, having been colored and preserved by the oxidation of some copper beads in contact." Fig. 111 is of one of the larger shell beads.

Council wampum

In distinguishing the modern council wampum from that which preceded it, and which could not have been used for the well-known and historic wampum belts, it may be well to speak of the origin of the name. It is not one originally used by the Huron-Iroquois,

nor could they even pronounce it. At first, too, it referred to the color of the shell beads, all varieties of which it at last embraced. Roger Williams said, in speaking of the aboriginal New England money: "Their white they call *Wompam* (which signifies white); their black *Suckauhock* (*Sácki*, signifying blacke)." Again he said that, after eating the clam called the hen, "they breake out of the shell, about halfe an inch of a blacke part of it, of which they make their *Suckaúhock*, or black money." Of the *Meteaûhock*, or periwinkle, "they make their *Wômpam* or white money, of halfe the value of their *Suckáwhock*, or blacke money." Wood says in his *New England's prospect*, of the industrious Narragansetts, "These men are the most curious minters of their *Wampompeage* and *Mowhakes*, which they forme out of the inmost wreaths of Periwinkle-shels. The Northerne, Easterne, and Westerne *Indians* fetch all their Coyne from these Southerne Mintmasters. From hence they have most of their curious Pendants & Bracelets." The New York colonists called it both sewant and peag. Holmes applies this latter name to the wampum of Virginia, but it is frequent in the colonial records of New York. Long Island has often been termed *Sewanhacky*, or the Sewant country. Its other aboriginal name of *Mattauwack*, variously spelled, according to W. W. Tooker comes from *Meht-anaw-ack*, or Land of periwinkles.

While shell beads were probably of early manufacture along the seashore, being made and used by the Algonquins, they were very little known in the interior and west of the Hudson before the 17th century. Accordingly we find few traditions of their origin among the river and shore Indians, while their use among the Iroquois was so sudden and conspicuous an event as to make a great and lasting impression. According to them the origin of wampum was coeval with that of their league. Hiawatha decreed and regulated its use. As far as they were concerned this is nearly the truth. The most earnest antiquarians have failed to find more than the merest trace of shell beads on any Iroquois site which can be dated before the year 1600, and have found none which are like the beads used in belts. It may be of interest to know what some of the Iroquois legends are, and some use may be made of them

in arriving at sound conclusions, even when told as simple tales of the forest.

In one story related by Mrs E. A. Smith, Hiawatha does not appear, but there is an obscure connection through the wampum bird. A man discovered this in the woods and hastened home with the news. The head chief offered his beautiful daughter to any one who would take the bird, dead or alive, and many were the arrows winged with this hope. Sometimes the bird was hit and off would fly a shower of wampum, speedily renewed on the strange visitor. No one could bring it to the ground. The best warriors despaired of success. Then came a little boy from an unfriendly tribe and wished to try his luck. This the warriors would not allow, and even threatened his life. The chief interfered. When warriors failed, a boy need not be feared, and his bow was bent. The swift arrow flew, the wonderful bird fell, and its plumage enriched the people. With the marriage came peace to two nations, and the boy decreed that wampum should bring and bind peace, and atone for blood.—*Smith*, p. 78. The feature to which attention is directed is that the first Iroquois wampum was of quills of some kind, according to this and some other legends. David Boyle gives this story in a larger form in his *Archaeological report* for 1899.

Another story, briefly related by Mrs Smith, is that Hiawatha came to a little lake while on his way to the Mohawks. While he was thinking how he should cross it, a flock of ducks lit on the water. When they flew off the lake was dry, and the bottom filled with shells. Of these the great chief made the first wampum for the new confederacy.—*Smith*, p. 64. This story is variously told, and some Onondagas now think the dry basin of one of the Tully lakes was the scene of this wonderful event. White and dead shells are so abundant beside all lakes and ponds that the ducks were hardly needed; and no fresh-water shells in those of central New York could have been wrought into wampum belts. The story is in line with Mr Morgan's statement, received from the Senecas, that the first Iroquois wampum was of fresh-water shells. The speedy introduction of beads probably prevented its general use. Horatio Hale mentions this story in his *Iroquois book of rites*, but leaves out the ducks.

Mr Morgan's statement may be quoted in full:

The primitive wampum of the Iroquois consisted of strings of a small fresh-water spiral shell, called in the Seneca dialect, *Ote-ko-a*, the name of which has been bestowed upon the modern wampum. When Daganoweda, the founder of the league, had perfected its organic provisions, he produced several strings of this ancient wampum of his own arranging, and taught them its use in recording the provisions of the compact, by which the several nations were united into one people. At a subsequent day the wampum in present use was introduced by the Dutch, who in the manufactured shell bead offered an acceptable substitute for the less convenient spiral shell.—*Morgan*, p. 71

It will be seen that these stories do not mention belts, and that Mr Morgan thought no existing belts antedated the Dutch settlement and trade. Dr Daniel G. Brinton was of the same opinion.

Another Hiawatha story was very briefly told by Mr Hale, but was given to the writer in full by the Rev. Albert Cusick, an Onondaga of great intelligence, and his own and Mr Hale's interpreter. When the wise and good chief determined to try to stop the constant Indian wars, he went first to the Mohawks. Not far from one of their villages he built a fire, and this was soon reported to the chief. He sent young men to see whether this betokened friend or foe. They crept quietly near and saw through the bushes an old man sitting by the fire, intent on stringing short eagle quills. He did not look up, and they returned and reported what they had seen. The chief sent them back to call the old man to a council. They approached him openly, but, when they gave their message, he neither looked up nor answered, and continued stringing the quills as before. They repeated the chief's words again and again, and, when they spoke the third time, he raised his head, holding up a string of quills and said, "When your chief would have me come to a council, he must send me a string like this." The quills were of the black eagle, a mythic bird that soars very high and is rarely seen. This wampum bird Hiawatha could call down at will. Such quills the Mohawk chief could not get, but he thought others might do. With those of the partridge he made a string and sent it to the old man. One story says he used colored wood. When Hiawatha came to the council, he first of all told them how

to make and use wampum. Then he showed how they might unite the hostile Iroquois nations and stop their frequent wars. The Mohawks were pleased with the plan, and went with him on his mission of peace. The usual Onondaga tradition is that their first wampum was made of porcupine quills.—*Beauchamp*, p. 295-305

It would be pleasant to follow Hiawatha and his friends to the several nations, but their adventures have nothing farther to do with wampum. Mr Hale maintained that his name had much in keeping, defining it as " He who seeks the wampum belt," and his words may be quoted from the *Iroquois book of rites.*

This name, which as Hiawatha is now familiar to us as a household word, is rendered " He who seeks the wampum belt." Chief George Johnson thought it was derived from *oyonwa*, wampum belt, and *ratiehwatha*, to look for something, or rather to seem to seek something which we know where to find. M. Cuoq refers the latter part of the word to the word *katha*, to make. The termination *atha* is, in this sense, of frequent occurrence in Iroquois compounds. The name would then mean " He who makes the wampum belt," and would account for the story which ascribes to Hiawatha the invention of wampum. The Senecas, in whose language the word *oyonwa* has ceased to exist, have corrupted the name to *Hayowentha*, which they render " He who combs." This form of the name has also produced its legend, which is referred to elsewhere. Hiawatha combed the snakes out of Atotarho's head when he brought that redoubted chief into the confederacy.

The Onondagas call this *Hi-e-wat-ha;* and Mr Hale's Onondaga interpreter told the writer that it could not mean the maker or seeker of the wampum belt. He came nearer to Johnson's interpretation, rendering it. " He who seeks something which he knows where to find." This would well describe the seeker for peace among kindred but alienated nations. Historically Mr Hale's definition will not stand, for it seems there was no true wampum belt in Hiawatha's day, and only strings appear in the stories. Some equivalent article there may have been. Philologically it seems as plain. The Senecas could not have lost the name for a belt, but *Hiawatha* is an Onondaga word, and wampum belt is *otekoa kaswentah* in that dialect. The chief was adopted by the Mohawks, and 200 years ago they called a wampum belt *gai-onni*, sometimes *gawenda*. The interpretation fails.

It will be seen that the writer utterly disbelieves the reputed antiquity of some belts, as any intelligent antiquarian will do on examination. After inspecting many he has yet to see one whose beads were not made with the white man's tools, or to find in New York an Iroquois site over 300 years old on which the peculiar belt wampum appears. One or two beads of about that age he has from the fort west of Cazenovia. It is every way probable that there was an earlier use and manufacture of good wampum with European tools, but it was not made or found in the interior. Vessels passed along the coast at a very early day, and left iron implements here and there, whose value was at once appreciated. Shell beads were more easily made and became more plentiful. They were used for money and ornament, but the Iroquois seem to have first used them in councils when strung. The true wampum belts naturally come later. Not till the beaver trade began to flourish, not till the Iroquois became strong, did they have many of those precious beads which for a long time were the gold and silver, even the pearls and diamonds of most of New York.

While only beads which were generally of a certain size and form could be used in such belts as we are accustomed to see, it is evident that uniformity would not be necessary in strung wampum, or in that used for ornamental purposes. Another kind of belt might be made of beads varying much in size and form. This was an early and rude variety, in which parallel strings of beads were tied together at intervals, forming a broad surface, but not one adapted for any elaborate design. Strings were of less value and importance than belts, but were often as much used. The only rule seems that of supply. Belts were preferred when they could be had, but when lacking strings did just as well. Beaver skins often took their place, and even sticks were used, but the latter were to be replaced with wampum when procured. Frequent instances will be found in our colonial records.

In an official way wampum does not seem to have been used by the Indians on the Atlantic coast. They had vast quantities of it in the 17th century, and its general use as money and for mere

ornament kept it from the honorable position assigned it by the inland nations. The two volumes of Holland documents relating to New York have no details of Indian treaties, and their first record of this official use relates to an instance when some Mohawks came to New Amsterdam in 1674, and presented six belts. In the 13th volume of the *Documents relative to the colonial history of the state of New York*, 13:35 we find an earlier use at Fort Orange, as might have been expected. It was largely used there, but in 1654 the Mohawks could already get more wampum for their beaver from the English than the Dutch. In 1657 the Mohawks gave the Dutch three wampum strings, worth respectively in florins 16.12, 16.9, and 13.10.—*O'Callaghan. Colonial hist.*, 13:72. Wampum belts were used there in January 1661.—*O'Callaghan. Colonial hist.*, 13:91. In early official use Canada, New York and Pennsylvania stand almost alone. The Huron-Iroquois family set the fashion, affecting those around. Less formally some Canadian Algonquins used wampum ceremonially, as in the raising of chiefs. The custom gained ground everywhere in historic times. Schoolcraft says the last belt of wampum was made to be used at a great peace treaty at Prairie du Chien in 1825, by the United States commissioners, Gen. William Clark and Gen. Lewis Cass. There are, however, several reputed Black Hawk belts.

As the supply of wampum was from the New England and New York coast, it was never so abundant in Canada, but among the Hurons it usually was arranged in collars or belts. Many of these were private property and of great value, though small. In 1636 a young Huron lost a belt of 400 beads and a beaver robe at the game of straws. In despair and fearing his relatives he hung himself. The following year the Ancients brought the Jesuits 2400 wampum beads which they had collected in the town. Some years before they had robbed Étienne Brulé of this amount, and they laid their misfortunes to this. There are other references to this strung wampum among the Hurons, but not such as indicate their ceremonial use of it in their own land.

In private life wampum became abundant while the beaver trade flourished. In 1656 some Onondaga warriors returned from the

Erie war during the *Honnonouaroia* or dream feast. They brought a message from Taronhiaouagui the Holder of the Heavens, of a curious nature. One requisition was 10 beads from each cabin and a belt 10 rows wide. The Onondagas did all that was asked. That year in the same town, "3000 grains of porcelain having been lost they consulted a diviner, who masked the face and hid the eyes to see more clearly that which they told him. He ran through the streets, followed by the populace, and, having run well, he went straight to the foot of a tree, where he found 2000 grains. He retained the third thousand to pay for his trouble."

Father Jogues sent 2000 beads to Onondaga in 1646, with an official message, and these must have been strung. Brébeuf 10 years before this gave 1200 beads in the Huron council, because all important speeches required presents, and this may be as far back as official strings appear. Then came three strings from the Mohawks in 1657. The Maryland and Virginia commissioners gave the Senecas a hank of sewant in 1682 with their propositions, and to the other four nations the same. They responded with beaver skins and belts. The custom grew with the English, and the Iroquois followed their lead. The Christian Mohawks gave three fathoms of wampum in 1691, and the whole nation did the same soon after. There was economy in this when the supply of wampum ran low in the last years of that century. Dekanissora gave a bunch of 48 hands of black and white wampum in 1699.

After that the use of strings for messages and councils became frequent. In Pennsylvania in 1707, Harry the interpreter laid "upon the board Six loose strings of white Wampum for his Credentials" from the queen and principal men of Conestoga.—*Penn. Minutes,* 2:403. Similar proof is required yet. Strings often replaced belts. At Onondaga in 1713, "the sachems called all together by order of the Five Nations, and spoke with three strings in their loftiest style." Wampum in hand they often speak yet. In 1756 the French sent a string of wampum to Onondaga to condole some losses. On strings of beads deaths are still condoled. In 1793 the Five Nations were called to a council of the Ohio Indians "by four double strings of black and white wampum." Color and number are yet of importance.

In William C. Reichel's *Memorials of the Moravian church*, p. 32, is an account of the string of wampum given to Count Zinzendorf. A note says:

This string of wampum was carefully preserved for the use of the brethren in their subsequent dealings with the Six Nations. On his return to Europe the count handed it over to Spangenberg, who gave the following receipt, written in Lamb's Inn (Broad Oaks), county of Essex, England, March 10, 1743: "This is to certify that Brother Ludwig has entrusted to me the token of a covenant ratified between him and the Five Nations or Iroquois, (which kind of token the Indians call fathom or belt of wampum) consisting of 186 beads,—given him by said Iroquois on the 3d day of August, 1742, on his return from the Indian country,—this, I say, is to certify that he has entrusted it personally, and in the presence of sundry eye-witnesses, to my safe keeping and for judicious use; which I desire hereby to testify by my own name in writing, with the promise not to give it into other hands, unless otherwise ordered.

AUGUSTUS S. SPANGENBERG.

De Schweinitz, in the *Life and times of David Zeisberger,* says of this wampum: "Spangenberg brought it back to this country, and it was often employed in subsequent negotiations with the Iroquois." This seems probable but is not very clear. Bishop Spangenberg does not refer to it in the journal of his visit to Onondaga in 1745, nor is it mentioned when Cammerhoff was there two years later. Other strings were then employed.

The Oneida chief, Abram Hill, gave the writer some wampum in 1878, with explanations of much that he had. Most of the large collection of strings and loose wampum was his own. There were no belts, nor were these often used in recent years on public occasions, many writers to the contrary notwithstanding. Most of his wampum was the black or purple, the white being now quite rare. Many of the strings were over a foot long, and some double that length. It may be doubted whether his arrangement was that invariably used, but the notes are given as taken at the time.

Six strings of purple wampum represented the Six Nations. These were united at one end, and the free ends were decorated with

tufts of bright merino without significance. When these strings were laid in a circle on a table, the council was opened. It was adjourned by taking them up. In this way a religious council was opened and closed at Onondaga in 1894, but not with the same wampum. The Mohawks, Onondagas and Senecas are elder brothers, and their special bunches for other purposes differed from those of the younger brothers, the Oneidas, Cayugas and Tuscaroras. The Mohawks had six strings in a bunch, two purple beads to one white, and the four strings of the Onondagas had the same proportion. In the four strings of the Senecas two purple beads alternated with two white. In the division of the younger brothers the Oneidas and Tuscaroras had each seven strings, in which nearly all the beads were purple. The six strings of the Cayugas contained no white beads. These strings were also tied in bunches, and were taken up and held in the hand by the speaker while addressing each nation. As each address was concluded one was laid down and another taken up.

The strings used in condolences are the most important now, but some are already disused. When a principal chief dies, a runner is or should be sent with the proper wampum to the other nations. He goes through the village calling *kwé*, three times at intervals if it is a principal chief, once if it is but a war chief. The wampum varies accordingly. Sometimes there are three runners a few rods apart. There are three small strings of purple beads united at one end for a member of the grand council, as in fig. 35, and a longer single string for a war chief, who is now the assistant of the other. This string has the ends tied, so as to form a circle, as in fig. 41. Attached to the message of any kind is a small stick, with notches to show the number of days to the council or condolence. The wampum is returned at the council, which is more fully described elsewhere. There is a growing disuse of some features, partly through the scarcity of wampum and increasing ignorance of proper forms. Invitation wampum may be used for feasts or any meetings, and even a grain of corn suffices for the 10 days' dead feast.

In the strings described to the writer 10 of dark purple beads were used if the chief's office was vacant by death. If he had lost his

office by marrying and settling in another nation, six short strings of purple wampum were employed. This was no disqualification except when an inconvenience. Mr Hill had married an Onondaga woman and yet was an Oneida chief. Such intermarriages are common, but necessarily affect only the children, who follow the mother's line. Through this it happened that the celebrated Logan was a Cayuga, his equally noted Oneida father having a wife of that nation. Three strings, united as usual, had a few purple beads and contained the new chief's name. He was to be "all good," signified by white beads, while the few purple implied some human imperfections. No allowance was made in the moral law, embodied in 10 very long strings, composed entirely of white beads. These were "all good, same as Bible." Whether the number of the strings had a meaning is conjectural. These strings were 2 feet long and each contained 110 beads. Fig. 31*a* represents a bunch of this kind belonging to the writer. Many others were about as long. Strings serve as credentials, and, armed with what was given him, the writer was informed that he would be listened to by any chief or in any council. It was a letter of introduction, a certificate of authority. Fig. 37 is this wampum.

It may be well to note here that the wampum in question varies much in size, the white being usually thicker than the purple, though this is not always the case. The beads are often more angular than cylindric, and, while the white is sometimes of a creamy tint, the purple passes through various shades, in which the layers of the shell appear. Three strands of purple wampum included a few white beads and were tied as usual. Each string contained 18 beads, and at the end of a condolence this bunch was presented to the three elder brothers. They were told to take it and divide it among themselves, but only did this figuratively. A doubled string of 48 alternate white and purple beads showed the death of a good chief. Two strands of 18 beads each were used in raising a chief. All but four of the beads were purple. Eight strings were used in the confession of sins at feasts. This handsome bunch was 2 feet long, and about every fourth bead was purple. To a large number of others meanings were attached as occasion required.

After the death of Mr Hill in 1895 most of his beads were delivered to the Onondaga and Oneida chiefs. His personal name was Ga-haeh-da-seah, Whirlwind, but his chief name was Ga-no-gwen-u-ton, Setting up ears of corn in a row. It appears on the treaty of 1666.

Of course other things might be used for invitations, as we have already seen. In his *Archaeological report* for 1890-91, p. 24, David Boyle describes some invitation quills which he had illustrated. They were for various occasions, and he quotes one use from the Rev. Peter Jones, among the Ojibwas.

A young man is generally sent as a messenger to invite the guests, who carries with him a bunch of colored quills or sticks about 4 inches long. On entering a wigwam he shouts out *Keweekomego*, that is, "You are bidden to a feast." He then distributes the quills to such as are invited. These answer to white people's invitation cards. . . They are of three colors, red, green and white; the red for the aged, or those of the *wahbuhnoo* order; the green for the *media* order, and the white for the common people. —*Jones*, p. 94-95

The writer has some mourning wampum, given him as a memorial of Abram Hill by his wife, and a similar keepsake from herself shortly before her death. Fig. 36 is the former. One mourning string, in another case, was attached to a large silver ring, fig. 33, and belongs to Albert Cusick, the ring being his mother's. Such tokens do not seem common. Some of these figures are reduced.

Fig. 34 has three strings of purple beads, each string terminating with white beads. Fig. 58 is a similar bunch. This was sometimes used in instructing a new chief. Fig. 39 and 40 are of fine purple and white beads, and might be used for any council purpose, or even for ornament. Fig. 42 is of much interest, though less showy. Out of thousands of old wampum beads of this class, these were all the writer could procure showing the aboriginal boring. This is much larger than usual, and wider at the ends than in the center, yet they may have been bored with steel awls. They are all white, and most of them are decidedly angular. In length they mostly exceed the common belt wampum. These are from Cayuga, and were associated with those having a smaller perforation, but which have an antique character.

Fig. 57 belongs to the writer, and contains a chief's name. Fig. 181 and 182 are bunches of strings in Mr Roddy's collection, arranged for council use. Fig. 195 is in the Bigelow collection, and is a miscellaneous lot of small beads from Pompey sites, some of which are much weathered. On Cayuga and Seneca sites they are found in thousands.

As the Iroquois were very punctilious on state occasions, the mere presentation of wampum was sometimes an honorable distinction. It was customary to receive the Five Nations at Albany with a salute from five cannon, but the French usually did more. When the Iroquois deputies went to Montreal in November 1756, they were surprised that no one came to meet them and that they were not received with the usual ceremonies. A note explains the meaning. In Canada "the Five Nations are the only ones for whose reception there is an established etiquet. An interpreter is sent to meet them, who presents them with some strings of wampum, and when they enter the town they are saluted by five discharges of cannon."—*O'Callaghan. Colonial hist.* 10:556

The Moravian bishops held a conference with some Seneca chiefs in Philadelphia July 17, 1749, and mention was made of Count Zinzendorf's wampum string. Von Watteville promised to visit Onondaga the following spring, and gave a fathom of wampum to confirm his words. "There was then handed to the interpreter a beautiful fourfold fathom of wampum of white and blue beads, with a large blue ribbon, who handed it to the Indians. It was received with great consequence, they studied over its meaning, and then wrapped it up carefully for preservation." John W. Jordan published the full account of this interesting conference from the diary of the congregation in the *Moravian* in 1898.

Abundance of wampum

Few antiquarians have any idea of the scale of supply for the wampum trade after the colonization of New York. Sir John Lubbock expressed surprise at the large number of beads sometimes found in early remains, when work was slower and methods ruder.

In speaking of this, William H. Holmes points out some historic examples in which the quantity was moderately estimated. The Onondaga belt which he cites is now 210 beads long by 50 rows wide, containing about 10,500 beads in its imperfect condition, and may have been double that size. In Barber and Howe's account of the wampum manufacture in New Jersey in 1844, it was stated that from 5 to 10 feet of wampum beads was a woman's ordinary day's work. This would be an average of 375 small beads daily, or about 112,500 for one person's yearly product. It was made in several places, and from 50 to 100 persons would carry the annual supply far into the millions. Furman says that several bushels of wampum were taken from Oyster bay in 1831. Elsewhere this is said to have come "from Babylon on this island, and the person who had this stated that he had procured this for an Indian trader, and that he was in the habit of supplying those traders with this wampum." In the days of the Dutch colony the average value of wampum was about 120 beads to the guilder. In 1664 Stuyvesant wished a loan of 5000 to 6000 guilders in wampum negotiated at Albany to pay the laboring people. This would have required over half a million beads and probably much more. In 1622 a Hudson river chief paid a ransom of 140 fathoms of sewant.

These few facts prepare us to understand the sudden abundance of wampum in New York and Canada, and the astounding statements in early New England history. Some of these are quoted from *Indian biography* by B. B. Thatcher, without farther credit. In treating with the Narragansetts in 1645 the commissioners, "to show their moderacon required of them but twoo thousand fathome of white wampon for their oune satisfaction," besides some equally mild conditions for Uncas. If the fathom is literal this would be but about 576,000 wampum beads. This was "moderacon" indeed. When 1300 fathoms were due, the Narragansetts sent into Boston 100 fathoms, which trifling quantity of over 28,000 beads the commissioners would not accept, though 70 fathoms had been paid the first year. A little later the Narragansetts brought in 200 fathoms more. An allowance of 20 days for paying another thousand fathoms was then granted. In 1649 the English acknowledged the

receipt of 1529½ fathoms and prepared to fight for the balance. In 1650 they said 308 fathoms were still due, and vigorous measures followed. All arrearages were paid on the spot. Smaller amounts were exacted or paid elsewhere, but all show the abundance of shell money. At a council at Albany in 1691, the Five Nations received a present of 1000 guilders in white strung wampum, equivalent to 150,000 beads.

Wampum as money

When Washington Irving wrote his humorous account of shell money among the Dutch colonists, many persons thought it a stretch of fancy, while in truth wampum was long the common currency. The New England colonists seem in a measure to have led the way in legal enactments, and many of these appear in the *Public records of Connecticut.* Wampum was there given an established value of four for a penny in 1637.—*Pub. rec. Ct.* 1:12. In 1640 it was ordained that "the late Order concerning Wampu at sixe a penny shalbe dissolued, and the former of fower a penny and two pence to be paid in the shilling shall be established."—*Pub. rec. Ct.* 1:6. It was again six a penny two years later. In 1648 it was ordered "that no peage, white or black, bee paid for or receiued, but what is strung, and in some measure strung sutably, and not small and great, vncomely and disorderly mixt, as formerly it hath beene." "The Commissioners were informed that the Indyans abuse the English with much badd, false and unfinished peage, and that the English Traders, after it comes to their hands, choose out what fitts their marketts and occasions, and leaue the refuse to pass to and fro in these Colonies, w[ch] the Indyans, whoe best understand the qualities and defects of peage will not willingly take back."—*Pub. rec. Ct.* 1:179

In 1648 Massachusetts ordered that wampum should be legal tender to the amount of 40 shillings, if good. White was to be eight for a penny and black four. It is also said that the use of wampum as money was unknown to the colonists of New England till 1627, when it was introduced by Isaac De Razier, secretary of New Netherlands, while on an embassy to the Plymouth colony.

This might be understood of its use by the whites, but an early historian lamented its introduction.—*Hubbard*, p. 40

There are some references to its value in the Holland documents. In 1650 complaint was made that no order had been received relating to wampum as currency in New Netherlands. The West India company answered that there was no currency among the common people there but wampum, which formerly passed at four for a stiver and was now six. Without regulating its value it was noted in 1634 that "wampum being, in a manner, the currency of the country, with which the produce of the interior is paid for, must be considered as obtained goods, being the representative thereof." In 1658 the sheriff of New Netherlands, acting as commissary, was selling goods in small quantities for wampum. Proposals for changed values were frequent. The Holland directors wrote in 1656: "We consider a change in the value of your currency, that is, placing the beaver at six florins instead of eight, and wampum at eight for a stiver instead of six, a matter of great importance which must be well considered." On this Gov. Stuyvesant wrote in 1660: "To reduce the price of wampum to 12 or 16 for a stiver, as we have reduced it from 8 to 10, in receiving it at our offices, will remedy the evil only for a brief period. The traders would give the length of a hundred hands instead of fifty." A stable metallic currency was needed.

The *Laws and ordinances of New Netherland*, 1638-74, contain many wampum laws. In 1641 rough and unpolished beads had been brought in, "and the good polished wampum, commonly called Manhattan wampum is wholly put out of sight or exported, which tends to the express ruin and destruction of this country." In 1647 loose wampum was to continue current, but imperfect, broken and unperforated beads were to be picked out and declared bullion. In 1650 loose wampum had depreciated from poor quality, and there were "many without holes and half finished; also some of stone, bone, glass, mussel shells, horn, yea even of wood and broken beads;" therefore it must be strung. Good should be six white and three black for a stiver; poor, eight white and four black for the same. It was to be legal tender only in limited quantities.

In 1657 it was too abundant, and grocers made a difference in prices of 30, 40 and 50% when selling for wampum or beaver. Being both long and short, it was to be paid by measure, yet a white bead was to be a half farthing, a black bead a farthing. In 1658 there was a greater difference in prices. Eight white and four black were to be a stiver, and a coarse wheat loaf of 8 pounds was to be seven stivers in silver, 14 in wampum; and a white loaf of 2 pounds was to be four stivers in silver and eight in wampum for the present. In 1662 wampum went down to 24 white or 12 black for a stiver. There was no duty on imported wampum.

In these constant changes wampum at last became scarce. The English felt this inconvenience soon after taking New York, and a proclamation was issued in 1673. "Where as ye great scarcity of wampum throughout these His Royal Highness his territories hath been taken into consideration, great quantities thereof being yearly transported and carried away by the Indians, and little or none brought in as formerly, which is conceived to be occasioned by ye low value put thereupon: And for that there is no certain coin in ye Government, but in lieu thereof wampum is esteemed and received as current payment for goods," to encourage bringing it in, "instead of eight white and four black wampum, six white and three black shall pass in equal value thereof as a stiver or penny, and three times so much in ye value of silver."

The running comments on this currency have some interest. In 1659, "wampum had already been reduced from six to eight for a stiver." It ceased to be valued "by counting so many for a guilder or stiver, but by the handful, length or fathom, and traders can afford under the circumstances, receiving more pieces for one stiver, to give a longer string to the natives for a beaver." In paying soldiers that year wampum was to be reckoned at a lower rate; and this reduced "the currency value of a beaver from 5 to 7 guilders. . . . This special reduction of wampum must necessarily be followed by a more general one, if we desire to prevent its complete debasement, caused by the abundant importation of wampum by the people of New England." They had quick returns in trade, while the Dutch sat "on their boxes full of wampum, a medium of

trade currency only among the savages of New Netherlands. So merchants here with whom we have consulted, fear that the natives may change their minds in this respect, and state that the tribes begin to incline towards another kind of bead, which they mix with the wampum for the sake of ornament." This was but a prospective evil. As yet the Indians wanted no gold or silver, but did want wampum. "Wampum is the source and mother of the beaver trade, and for goods only without wampum we can not obtain beaver from the savages. If we receive no wampum from outside—we have none in our country—this would certainly cause a diversion of the beaver trade." In losing part of Long Island much of the wampum supply was lost, though by no means all. The colonists complained in 1649 that "the English tried to exclude Dutch from Indian trade, so as to have all the profits of the wampum trade." The following year Van Tienhoven said that Gardiners bay was "well adapted to secure the trade of the Indians in Wampum, (the mine of New Netherland) since in and about the abovementioned sea and the islands therein situate, lie the cockles whereof Wampum is made, from which great profit could be realized." It is added that "the greater part of the wampum is manufactured there by the natives." The preceding year it was said that Indian "money consists of white and black Wampum which they themselves manufacture; their measure and value is the hand or fathom."

Other articles fluctuated in price with wampum. In 1648 trade had been injured by Indian wars. The Dutch had to "give two fathom of white and one of black wampum for one beaver. . . Each fathom of wampum contained three ells; some one-sixteenth less. The Indians select the largest to trade." The prices established in 1657 were "for a merchantable beaver two strings of wampum; for a good bear-skin, worth a beaver, two strings of wampum . . . for a deer-skin 120 wampum." In 1660 the Senecas would come and trade with the Dutch if they would give 30 handfuls of black or 60 of white wampum for a beaver. In 1655 beavers were valued at nine guilders in repaying 1500 guilders of black and white wampum. We need not quote its many other uses in trade, except that part of the payment to the Mohawks for lands west of

Schenectady in 1672, was 600 hands of good white wampum. At that time a fathom string varied from five shillings in New England to four guilders, or $1.665 among the Dutch.

In John Winthrop's *Journal*, 1:136, is an item of some importance regarding the early use of wampum as money. It is under the date of July 9, 1634. The magistrates of Plymouth came to Boston to consult about the Kennebec country. They had traded there many years, and "had by this providence, drawn down thither the greatest part of the trade by carrying wampompeage thither, which none of the English had known the use of before." This harmonizes with the statement that the Dutch taught them its use in 1627. Gov. Bradford's words on this seem conclusive as to its introduction into New England at an early colonial day. He was the second governor of the Plymouth colony, and wrote a history of the plantation. In his record of the year 1628 he speaks of this visit of the Dutch to Plymouth and of the English to Kennebec, but his statement has never before been given and is here quoted nearly in full.

" That which turned out most to their profite, in time, was an entrance into the trade of Wampompeake; for they now bought aboute 50^{li} worth of it of them; and they told them how vendable it was at their forte Orania, [Aurania, now Albany] and did perswade them they would find it so at Kenebeck; and so it came to pass in time, though at first it stuck, & it was 2 years before they could put of this small quantity, till y^e inland people knew of it; and afterwards they could scarcely ever gett enough for them, for many years togeather. . . And strange it was to see the great alteration it made in a few years amonge y^e Indeans themselves; for all the Indeans of these parts, & y^e Massachusetts, had none or very little of it; but y^e sachems & some spetiall persons that wore a little of it for ornaments. Only it was made & kepte amonge y^e Nariganssetts & Pequents, which grew rich & potent by it, and these people were poore & begerly, and had no use of it. Neither did the English of this plantation, or any other in y^e land, till now that they had knowledge of it from y^e Dutch, so much as know what it was, much less y^t it was a comoditie of that worth & valew. But after it grue thus to be a comoditie in these parts, these Indeans fell into it allso, and to learne how to make it; for y^e Narigansets doe geather y^e shells of which y^{ey} make it from their shors. And it hath now continued a current comoditie aboute this 20 years, and it may prove a drugg in time. In y^e mean time it maks y^e Indeans of these parts rich and power full, and allso prowd therby; and fills them with peeces, powder, and shots, which no laws can restraine.—*Bradford*, p. 234-35

Poor wampum would naturally sometimes be found, and allusion has been made to this. This was mostly in New England, where the material was inferior to that of Long Island. In the Winthrop papers, (1644) one writer complains of this. "As for the blew wampom there is 18*s*. of it, at 3 a peny, but I will not take such as this vnder 6 a peny. I had rather haue white wampam, then bad blew at 6 a peny. I will kepe it, because you may redeeme it for white."—*Winthrops. Letter*, p. 377

Though the Iroquois quite recently used wampum as money, our latest trace of it in this way among ourselves may be in 1693, when "the ferriage for each single person from New York to Brooklyn was eight styvers in wampum, or a silver two-pence."—*O'Callaghan. New Netherland*, 1:61

Poor wampum was refused in New Amsterdam in 1650, and the authorities then ordered "that badly strung wampum shall be current money, and be accepted as such by everybody without distinction or exception, for small and necessary commodities used in the house, and that it shall be current up to the sum of 12 fl. and less in badly strung wampum, in sums between 12 and 24 fl. in half bad, half well strung beads, from 25 to 50 fl. one third bad, two thirds good wampum. . ."—*Fernow*, 1:17

Ornament

Wampum was often used for personal decoration. The Jesuits said that the Hurons (1638) wore "around their necks and arms necklaces and bracelets of porcelain. They also suspend them from their ears and around their locks of hair." In Sagard's *Grand voyage* (1632) he speaks of shell beads among the Hurons which were apparently large. "These shell beads (*pourceleines*) are the bones of those great seashells which one calls vignols, similar to snails, which they cut in a thousand pieces, and polish them upon a piece of fat. They pierce these, and make collars and bracelets of them with great toil and labor." These were very unlike the small council wampum made from the Venus mercenaria. They called them *onocoirota*, and they were valuable. For ornamental use "the beads are differently threaded. Some colored ones, three or

four fingers broad, are like the saddle girths of a horse which would have the pack threads all covered and threaded with them. These collars are about three and a half feet in circumference or more, which they put in quantities on their necks according to their ability and wealth. Then others are threaded like our paternosters and fastened to and hanging from their ears. There are some chains of beads of the same porcelain, large as nuts, which the women fasten upon the two hips and which come in front, arranged in order perpendicularly above the thighs or trusses which they wear." These were ornaments fit for their divinities. They told the Jesuits (1636) that *Ataentsic* sometimes took the form of a beautiful girl, "adorned with a fair collar and bracelets of porcelain."

The Hurons told a curious story of some of these shells which seems to belong to the Gulf states, being connected with another in which alligators appear. The Jesuits said (1641):

Some old people used to tell our fathers that they had knowledge of a certain western nation against whom they were going to make war, which was not far from the sea. That the inhabitants of the place fished there for periwinkles, which are a kind of oysters, the shell of which serves to make the porcelain which are the pearls of the country. This is the manner in which they describe their fishing. They notice when the sea rises to the places where these periwinkles abound; and when the violence of the waves pushes them towards the shore, they dive into the waters and seize those which they can catch. Sometimes they find those so large that it is all they can do to hold them.

The Jesuits took advantage of this fondness for ornament. At Oneida (1670) Bruyas gave a string of glass beads, two long bugle beads, or two bronze rings as rewards. He recorded many Mohawk words relating to wampum and its uses. A set phrase was used when wampum was cast on a corpse, to comfort the mourners. The Mohawk name of this ceremony was *gannonton*. The same writer (before 1700) called wampum *ondegorha;* a string of wampûm *onnongwira*, and a belt *gaionni*. *Garensa* was a string of glass beads. Arent Van Curler (1635) gave the name of *onekoera* to wampum, and *eytroghe* to glass beads. To Bruyas we owe the mention of "*gannisterohon*, dance of the Agoianders, where they give wampum to the spectators." This was a dance of the nobility which has

disappeared, and it seems to have been a largess. They provided wampum for many occasions. *Onniatsara* was the "porcelain which the women attach to the hair which hangs back of the head."—*Bruyās*, p. 75

Zeisberger's Onondaga dictionary has many Mohawk words. In it wampum appears as *otgora*, a belt of this as *gaschwechta*, and a string as *ganachsa*. The Seneca name of a shell bead is *otekoa*. In the note to Montcalm's letter of April 24, 1757, taken from Lafitau, we are told that the belts were commonly called *gaionne;* also *garihoua*, an affair, and *gawenda*, a speech or message. Another name was *gaianderenscra*, greatness or nobility, as chiefs only were employed in affairs requiring belts. They furnished belts and strings, and the wampum was divided among them when presents were made and answers given. Among the Onondagas now wampum is called *ote-kó-*, a wampum belt is *ote-kó- -ka-swén-tah*, and a wampum string *ote-kó-ă-ka-náh-sah*. Not long since they used it as money, and persons yet living have been paid in this.

Pictures of women adorned with large beads appear in accounts of Champlain's voyages. The French also observed that the Canadian Algonquin women, in 1639, "wear their hair in a knot at the back of the head, in the form of a truss, which they ornament with porcelain when they have any." An Iroquois chief, who was killed in an attack on the French in 1642, wore "a kind of crown of deer's hair tinted scarlet, with a collar of porcelain." In an account of differences between Indians and Europeans, written in 1658, it was noted that the savages wore bracelets about their elbows and ankles as well as wrists. Men wore wampum collars more than women. They wore small wampum beads variously strung, chaplets of beads, little tubes of glass or of shells. This relates to Canada.

In an account of New York Indians in 1649, it is said, "They twine both white and black wampum around their heads. Formerly they were not wont to cover these, but now they are beginning to wear bonnets and caps which they purchase from the Christians. They wear wampum in their ears, around the neck, and around the waist, and thus in their way are mighty fine." Arnoldus Mon-

tanus said in 1671, "The clothing of the New Netherlanders is most sumptuous. . . All wear around the waist a girdle made of the fin of the whale or of seawant. . . The women wear a petticoat down midway the leg, very richly ornamented with seawant, so that the garment sometimes costs 300 guilders. . . The women bind their hair behind in a plait, over which they draw a square cap thickly interwoven with seawant. They decorate the ornaments for the forehead with the same stuff. Around the neck and arms they wear bracelets of seawant, and some around the waist."—*O'Callaghan*, 4:125-28

Prisoners were sometimes treated with the greatest kindness and distinction before being tortured, and this was done at times by both Hurons and Iroquois. Some Andastes were brought in triumph to Onondaga in 1670, and had this honor. For a while before their torture "they crowned these poor victims, according to custom, with the rarest feathers and the most beautiful porcelain that could be found." In the curious account of the kind treament of an Iroquois prisoner by the Hurons, preliminary to his torture, *Relation* of 1637, p. 110, we are told that "he was clothed in a beautiful beaver robe, he had a collar of porcelain about his neck, and another in the form of a crown about his head." Thus clad, Brébeuf added, "Even to the hour of his torture, we saw exercised on his part nothing but traits of humanity."

Such observations on mere adornment might be indefinitely extended, but it will suffice to refer to the wampum pipes and small round shells included in the presents of 1702. The pipes were the long tubular shell beads so often found, and the round shells probably the ornamented and perforated disks, or runtees. They were tasteful as well as showy, and both were then in use.

In 1605 Champlain found the Indians on the New England coast wearing shell beads. He observed, 10 years later, that the Hurons wore bands of porcupine quills dyed scarlet. Beside these, shell beads were also much worn, but apparently of a large size. The French always called these porcelain. When Jacques Cartier visited Hochelaga, now Montreal, in 1535, he told a strange story of the *esurgny*, which was white and their most precious possession.

This "they take in the said river in *cornibots,* in the manner following. When any one hath deserved death, or that they take any of their enemies in warres, first they kill him, then with certain knives they give great slashes and strokes upon their buttocks, flankes, thighs and shoulders; then they cast the same bodie so mangled downe to the bottome of the river, in a place where the said *esurgny* is, and there they leave it ten or twelve hours, then they take it up againe, and in the cuts they find the said *esurgny,* or *cornibots.* Of them they make beads, and use them even as we doe gold and silver, accounting it the preciousest thing in the world. They have this vertue in them, they will stop or stanch bleeding at the nose, for we proved it."

All writers have considered these shell beads. Sir J. W. Dawson said, in *Fossil men,* p. 32: "It is probably a vulgar local name for some shell supposed to resemble that of which these Indians made their wampum. I would suggest that it may be derived from *cornet,* which is used by old French writers as a name for the shells of the genus Voluta, and is also a technical term in conchology. In this case it is likely that the *esurgny* was made of the shells of some of our species of Melania or Paludina." Neither of these shells is white unless very much worn. The Paludina or Melantho is green, burrows in mud along the shore, and is thus easily procured. The Melania or Goniobasis is of a dark yellow, or brown, does not burrow as a rule, but adheres to stones in shallow or deep water, and can be as readily gathered. Both seem vegetable feeders.

Charlevoix refers to this story. "James Cartier in his memoirs makes mention of a shell of an uncommon shape, which he found, as he says, in the island of Montreal; he calls it *esurgni,* and affirms it had the virtue of stopping a bleeding at the nose. Perhaps it is the same we are now speaking of, but they are no longer to be found in the island of Montreal, and I never heard of any but the shells of Virginia which had the property Cartier speaks of."

Hardly any shell beads have been found at Montreal or on the earliest Mohawk sites, and the story has an extravagant appearance. If it is to be received, the writer has already suggested a possible

solution. The fresh-water lobster is carnivorous, and its long horns might suggest the term, *cornibots*. Back of the eyes are sometimes found small, white, polished and half globular substances known to most country boys as eyestones, and used by them for very simple surgery. Fig. 10 shows one of these. To make a fair bead they would require only perforation. They are often called eyestones because placed very near the eyes, while really in the stomach of the crustacean. Hence they are more properly known to naturalists as gastroliths, or stomach stones. Very often they are not found, being absorbed about the moulting season. This would add to their value. On the other hand, no such beads have ever been reported in any way, and they must have had a limited range if used at all. Their small size may have caused them to be overlooked, as it would have contributed to their loss or rapid decay. It should be noted that the *esurgny* were not the same as the *cornibots*, but were taken in them. To a practical naturalist, acquainted with the forms and habits of all New York and eastern Canadian fresh-water snails, this seems the possible solution of a puzzling statement, though it may appear absurd to some. In fact, Cartier's story seems, itself, absurd.

From their variety and importance the writer has treated beads separately, as well as some other classes of ornaments. Those of a more miscellaneous character may be grouped here.

Among these are some which may be called flattened or disk birds. They are rather thin flat pieces of shell, cut into a more or less bird-like form, in general outline somewhat like a plump duck. There is a short neck, sometimes expanding into a small head. For suspension they are perforated longitudinally through the neck. All those figured are of actual size except one. They came into use about 1660 or a little later, and occur on most recent sites for a century more. Good examples have been abundant on Indian hill, Pompey, occupied from 1650 to 1681. Fig. 215 from that town, is reduced in size. A great many have been found on Cayuga sites, and fig. 76 is a good example out of some found at Fleming. Fig. 73 is of white shell, and comes from Cayuga county. One from Happy hollow, a little west of Canajoharie, has a small

head and an unusually long neck. Fig. 75 shows this. Fig. 77, of dark purple, is from the McClure site near Canandaigua, and there are good examples in the fine collection of Raymond Dann, made just west of Honeoye Falls (N. Y.) The form is very frequent on Seneca sites, and purple shells were commonly employed.

Distinct bird forms occur in shell, with some of a doubtful character. Fig. 89 is of an owl in A. G. Richmond's collection, and found near Canajoharie. Fig. 72 is of a larger ornament in the collection of W. L. Hildburgh, of New York city. This is from the recent site at Oneida Valley, occupied after 1750, and may have represented a flying bird. Fig. 91 is a fine owl from the Dann collection, and is ornamented with lines and dots. Though made mostly from one site, this collection is unequaled in New York in its array of articles of shell. Fig. 97 is a broken bird, ornamented with dots and lines, and is from the same site. After being broken at the neck it was drilled again for suspension, through the short diameter at the base. Fig. 92 is from the same collection and is much weathered. The details having been lost, it may possibly have been a mere pendant. Fig. 93 represents an intermediate form in this collection. It is much weathered, but has the usual perforation in the neck. Though of the class of ornaments immediately following, it is less symmetric, and of unusual length and width. Fig. 90 is a very rare form from Venice (N. Y.), made from a bivalve shell. Fig. 94 is a fine expanded example from Canajoharie. Fig. 66, belonging to Mr Hildburgh, is a bird from Oneida Valley.

Among the most common articles in bone and shell are those suggestive of birds, of slender form and with long necks and heads. They have a single lateral perforation through the neck, and are often broken at that place. While rarely plain, the ornaments are mere lines and dots, and the material is quite as often bone as shell. Fig. 218 is from Pompey and is the only one represented less than the actual size. Fig. 60 is a broken one from Munnsville, ornamented with lines alone. Fig. 65 was found by W. W. Adams on the site of old Cayuga castle, with many others. This is purple, but they are usually white. Fig. 70 is a large and fine one of the same hue, and from the Sibley farm, Foxridge. A lateral view is

given, showing the perforation. Fig. 263 is from Indian hill, Pompey, 1650-81. Hundreds of figures might be added from recent sites. One curious form appears in fig. 63 of actual size, and in fig. 217 reduced. It represents a conventional quadruped, and is from Indian Castle, Pompey. A broader form from the same place is more like a turtle, and is much reduced in fig. 216. Both these are in the remarkable collection of O. M. Bigelow, Baldwinsville (N. Y.) Fig. 61 and 68 are from near East Bloomfield, and are in the Hildburgh collection.

Other common ornaments, somewhat resembling these, are often called crescents for want of a better name. These little ornaments may be either of bone or shell, are moderately curved, pointed at each end, and have a double perforation for suspension. Mr Hildburgh has a number of these from a recent grave at Oneida Valley, arranged as they were found. There were 16 of the crescents, strung with 36 shell beads, the double rows of which kept them apart. Fig. 62 shows four of the crescents thus arranged with the beads. Fig. 83 shows one of more than usual size from Indian Castle, Pompey. Eight, from the same place, appear much reduced in fig. 200. These are now in O. M. Bigelow's collection. Fig. 69 gives two views of one from the site of East Cayuga. They abound also on the Seneca and other recent sites.

Some of the finest finished articles represented turtles; and it has been a favorite, but not well grounded idea, that these were personal totems. Had this been the case, other clan symbols would have appeared, whereas they are either rare or unknown, as will appear from their omission here and the presence of others having no significance. They were simply ornaments, as the writer finds is the case with the later ones of silver. Fig. 98 is a good example of one of these turtle forms, ornamented with lines and dots. This was found in 1890, on the *Onahee* site, McClure farm, Hopewell (N. Y.) Some of the best specimens are from this site. Fig. 99 is from the same place, and is of the same form. Four lines of dots are inclosed by semicircles laid out with compasses. Fig. 103 is of a still finer example found there, but which has unfortunately lost its head. It is much larger and broader than usual, and is

ornamented with dots and lines. Fig. 95 is remarkable for its material, being of oyster shell. The eyeballs are strongly marked, and it has been broken off at the hinder limbs. This is in the Dann collection. Fig. 96 is another good example of the turtle ornamented with half circles and dots. It is from Pompey, and was in the collection of the late L. W. Ledyard of Cazenovia. Fig. 74 is another rude example from Pompey, possibly early. Fig. 102 is an animal form from a Cayuga grave, and may have lost its head, necessitating a new perforation. It is ornamented with dots in rows. Fig. 100 is a beaver with its scaly tail, and is from the *Ganagarae* site, lot 13, East Bloomfield. It is made of a very durable shell, and is 1.75 of an inch long. The neck is perforated as usual.

Fishes have no significance as clan totems, but good examples occur in shell and stone. Fig. 101 is one from Cayuga. They all have two vertical perforations, one on either side of the dorsal fin. Fig. 104 is of one broken at the forward hole. Fig. 212 is from a reduced photograph of the same. It was found at Indian Castle, Pompey, and was therefore made in the last half of the 17th century. With the following two it is now in the Bigelow collection. All three are from Pompey. Fig. 59 lacks the dorsal fin, and the holes are on either side of the ventral fins. It is quite suggestive of the sturgeon, but lacks some features. Fig. 105 is much the finest of these, possibly intended for a black bass in spirited action. It is of a hard and highly polished shell, and is ornamented with diagonal lines inclosing dots.

Cylindric pendants are not common or large, as few shells would afford material for these. Fig. 67 and 71 are of two in the Hildburgh collection and are 1 inch long. Both are from the McClure farm, Hopewell. Fig. 31 is of another, quite large and thick, which came from the Van Arsdale farm, Fleming (N. Y.) Those which are thin and flat are much more common. Fig. 32 is large, angular and flat, with one perforation in which is a copper ring, and comes from Indian hill, Pompey. Fig. 78 is of nearly the same form, but is thin and has a small perforation at each end. It is in the Dann collection. Fig. 88 is from Hopewell, is quite flat, and has

a vertical perforation. Fig. 86 is a small flat pendant from Indian hill, Pompey.

Discoid beads

Early flat or discoid shell beads are somewhat rare in New York. The writer has found but one antedating the year 1600; and some other collectors have been no more fortunate. Some occur on an Onondaga site of that period, and on another occupied by that nation about 1640, nearly all the shell beads are small disks. Later than that there are few in that county. They are not so rare on more recent Seneca town sites, and have been found on several in large numbers. From a recent Oneida town site has also come a fine lot of very small ones, mostly quite thin, and both purple and white. These belong to the writer, and are shown in fig. 38, with a tooth and two other beads. These soon gave place to the more showy council wampum.

Mrs Converse obtained a string of small and irregular disk beads, for the state museum, about 46 inches in length, which she called "Canadian Algonquin wampum." The ends of the string are united by a large, red ribbon, and at intervals are brownish red, orange yellow, and light and dark blue ribbons. She says: "This string belonged to the old bunch which was sent by the Algonquins to the Mohawks, long before Brant's time, as a ransom for an Algonquin captive. The Mohawks carried it with them when they ruptured the league of the Iroquois, and departed with Sir John Johnson and Brant. The original bunch was strung on sinew. In the various divisions thread has been substituted. Originally the bunch was decorated with various colored feathers, which have been replaced with the more modern ribbon. Red signifies war, light blue the morning sky, yellow the sun, dark blue the noon sun, maroon or very dark red the approaching of the night shadows. Each decoration signifies the division of the story of this wampum, which was recited at the ancient councils. This string has been preserved as a record and not used in modern times. I believe this to have been constructed before the pictograph wampum belts.—*Grand River reserve, Canada*, June 7, 1899." Fig. 233 shows this.

The Iroquois had Algonquin captives in hundreds. It is possible such a string may have kept the general fact in memory, but the ransom went to the owner of the captive. The tradition seems defective in some points, but the beads are probably of moderate age. The eastern Iroquois used this kind sparingly from 1600 to 1640, and the earliest record of pictograph wampum belts was a dozen years later. On the other hand, the disk beads were fine and abundant among the Senecas as late as 1700, and not rare with the others. They were recently and largely in use in our western territories, and were divided by stones instead of ribbons, each division having an extravagant trade value. One in the hands of the writer would have bought several horses. In his experience colored ribbons or bright cloths are used merely for a pleasing effect, but in important affairs some colors become emblematic. In this instance the dark blue ribbon has been added since 1893.

With slight exceptions New York discoid shell beads date from the latter part of the 16th century, becoming most abundant during the next hundred years. Sir J. W. Dawson informs the writer that the only shell bead he found at Hochelaga was of this kind, but the longer marine beads have sparingly appeared on that interesting site, and may be of any age. A few New York examples will be given. Probably the earliest yet found was in the curious and early cemetery reported by S. L. Frey, a little east of Palatine Bridge. Mr Schoolcraft, in his *Notes on the Iroquois*, p. 142, figured a large disk bead from Onondaga, and had found others in the Neutral ossuary in Beverly, Canada. He says these were first disclosed on opening the Grave creek mound in 1839. His general description of this form is good. "Decomposition gives its surface a dead white aspect and limy feel. The powder scraped from the surface effervesces in acids. It is generally, not uniformly, an exact circle, and resembles extremely a very thick horn button-mould." His New York specimen is of the 17th century, and we can not uphold his conclusion that "its occurrence in Onondaga denotes the universality of the art in the ante-European period." These flat beads were used at an early day, but a recent example is no proof of this.

It is rather surprising that these seem to have no very early date on Long Island. Our best authority on that region, W. W. Tooker of Sag Harbor, writes: "I have seen discoid and other shell beads from graves here. The graves were about the year 1662 in one place, and about 1700 in another. I have never seen any from ancient graves. The graves here in which I discovered two vessels of clay, contained no beads or ornaments of any kind." Their absence is but negative testimony, but on the whole they seem to have had no great antiquity in New York. Quite a number from Pompey appear on the same plate with the largest gorget. These are not separately numbered; and all are recent, and reduced in size in fig. 206 and 221.

Fig. 197 on the same plate, is of a string of these, about 80 in number, which were found near the canal lock, 1½ miles north of Cayuga, in the town of Aurelius. They seem of early date, being of irregular thickness and form, and have some ridges on the circumference. They are much reduced in this figure. All the others on this plate are from Pompey, and all are in the Bigelow collection. Apparently this string contains the oldest yet found, unless a small one with the stone tubes in the Palatine Bridge grave should prove earlier. All the rest of seashell to be noted are recent, and of actual size.

Fig. 256 and 257 represent two of very large size, found at Cayuga, along with others very small. Fig. 27 is from Indian hill, Pompey, and is very neatly made. Fig. 21 is an example out of many small ones, with quite large perforations, from Union Springs. They are quite frequent in graves east of Cayuga lake. Out of one grave were taken 124 small ones, and out of another 72 with large perforations. Unios furnished the material for the first of these two lots, and they are represented in fig. 21. Some Venice beads are thin as paper. One was found north of Fort Plain, exactly like fig. 27, and the form is frequent in the Mohawk valley. Many large and small occur at a site south of Pompey Center, occupied about 1640. They are abundant on recent Seneca sites, and small ones have been found at the early fort west of Cazenovia. A fine, large disk bead of Unio shell, represented in fig. 14, was

found by the writer on a fort site near Baldwinsville, a few years older than the last mentioned. The outer side, next the epidermis, is ground flat, while the nacre on the other side is left undisturbed. The central perforation was mostly made from one side. Such ornaments are extremely rare. With so common and fine a material this is at first surprising, but it may have been neglected because common. A worked piece of this which is unfinished, is from the fort west of Cazenovia. A thin ornament of this, represented in fig. 220, has also been found in Pompey. Fig. 125 is an unperforated disk of pearl from the mission fort site at Onondaga lake. Unio complanatus shells, however, are abundant on early Mohawk sites and some others, the mollusk having been used as food. The other and finer species rarely appear. Fig. 38 is a string made up mostly of very small disks from near Munnsville, and has been already described. Fig. 266 is a Cayuga bead with an inside rimming. This is a rare feature.

Massive beads

Mr Holmes gives several forms of massive beads on page 224 of *Art in shell*, some of which are frequent and fine on recent New York Iroquois sites. It must be remembered that most shell articles in this state west of Albany are not prehistoric. His plate 34 gives examples of a class which he says "are more decidedly aboriginal in character than those of any other group, and are without doubt of very ancient origin. They are widely distributed, and have been found in graves and mounds covering an area outlined by Massachusetts, Canada West, Minnesota, Missouri, and the gulf and Atlantic coasts."

Some of those represented are modern in character and are found in New York. Others have not yet appeared there. His fifth example is from Monroe county, N. Y., and presumably from the site near Honeoye Falls, where shell pins and European articles have been found. The form was largely used there and elsewhere in the last half of the 17th century. The Swanton bead belongs to the same period, and some California forms differ little from recent examples in New York. While long cylindric shell beads or wam-

pum pipes are common on recent Iroquois sites, the shorter and thicker beads are often angular, but disks and spheres are by no means rare. Out of a large number of the thicker and shorter beads some characteristic forms are shown.

Fig. 196, 198 and 214 from Pompey present several much reduced, which are in the Bigelow collection. Fig. 106 is of actual size, as are those which follow. The angles are rounded, and in section it follows the curve of the shell. This is from Indian hill, Pompey, occupied from 1650 to 1681. Beads of this class range from small to large sizes, and vary much in form. Fig. 84 is a long, flat bead, of moderate thickness, found on the Dann farm near Honeoye Falls. Fig. 130 is from the same site, and is triangular in section. Massive beads have been abundant there. Fig. 136 is somewhat spheric, and is from the same site. Fig. 109 is a large bead from Scipioville, where similar forms are frequent. Fig. 112 is from a recent grave at the East Cayuga site. Fig. 114*a* comes from Venice in the same county. This somewhat cordate form is frequent there. Fig. 151 is larger, but resembles the last. Fig. 141 differs slightly from these, and is from the same town. Fig. 107 is a longer form from Pompey. Fig. 113 is another of these large heads, most of which are flattened. Fig. 129 is a large angular bead, also from Pompey. Fig. 137 is similar and smaller. Fig. 152 shows another bead from the same town, almost cylindric. Fig. 150 comes from Baldwinsville, and resembles the last except in being triangular in section. To these many might be added. Sometimes there is a double perforation part way, and in one case a fossil shell has been used. Large shell beads are more common from Madison county to the Genesee river than farther east, and can only be expected on town sites or in graves. Almost all are recent. Fig. 204 is a globular bead from Pompey, and fig. 213 a short cylindric bead from the same town. Both are reduced.

Long beads

The name of wampum pipes seems to have been applied to long cylindric beads about the size of common pipestems, and which resemble them when weathered. Fig. 193, 194 and 207 show strings

of these much reduced in size. Fig. 219 is similar, and has an ornament attached. These are all from graves in Pompey and are in the Bigelow collection. When taken from graves, there is often more or less of a coating of a brown substance, perhaps from contact with the flesh. This appears on several of these. As a standard of measurement the extreme width of the largest gorget on this plate is 5.25 inches. Where beads are as slender as these all traces of the species are usually obliterated, and many of them may have been made by the colonists for the Indian trade, all of these slender ones being recent. They are frequent on many sites and are quite uniform in character.

Fig. 115 is a good example of this class from East Cayuga. It is 4.75 inches long and well polished. The harder shells often retain this polish, while the softer easily corrode. Others were found with this one. Fig. 127 has a similar polish, but is much shorter and less slender. It came from Geneva. Fig. 131 is one of four very long beads from Pompey. It is 5 inches long. Fig. 132 is 4 inches long, and is but one of a number of this size from the same town. They are so closely alike that no more illustrations are needed here.

Much more interesting individually, and often more antique, are the ruder columella beads. Fig. 111 is from the noted Palatine Bridge graves, and from association seems quite early, though its character is less antique. Apparently it was made from Fulgur carica, but a similar bead with it was of Busycon perversum. There were also shells of Melampus bidentatus, a small marine marsh species. Fig. 110 much resembles these, and was found by the writer on a site on Seneca river, probably not far from 350 years old. Fig. 108 is from a similar site north of the last and just across the river. It was found in 1893. Both these are nearly of the same age and are made of Fulgur carica. Fig. 118 is of the same material, but has a more definite date. It was found at the Onondaga fort west of Cazenovia, and therefore is about 300 years old. It is doubtful whether Busycon perversum had reached that vicinity so early.

The finest columella beads have come from Cayuga county, and

a great age has been claimed for some of these, when found distinct from European articles. As those of the same character occur in recent graves it seems most probable that all are of about the same age, though not proved to be so. The writer detects nothing in the features of the one article which does not apply to the other, but leaves the question of age open for the present. W. W. Adams, now of Union Springs, has long been an indefatigable worker in this field, and to him the writer is indebted for many favors and much aid.

Fig. 135 is a fine and well worked columella bead, found 1½ miles north of Union Springs. It is of Busycon perversum, and there can be no doubt of its modern character. Fig. 262 found on the recent site at Scipioville, seems to be formed from the columella of Sycotypus canaliculatus. Fig. 121 is one of the finest of these beads on record, being 6.8 inches in length. It is from Cayuga county and is made from a large Busycon perversum. Fig. 133 and 134 are of large and polished beads from the St Joseph's mission site near Union Springs. Long beads of Busycon have been found at the same place. Fig. 120 is one of an interesting series from the same place, and is 6.15 inches long. 10 of these Busycon beads were found together in 1887, four of them aggregating 22 inches in length, and the remaining six the same. Many interesting examples might be given from those obtained by Mr Adams, now scattered in various collections. Through his kindness most of the important Cayuga relics have been drawn and described by the writer.

Fig. 119 is a Busycon columella of great interest, because, while ready for use as a bead in other ways, it is unperforated. It is in the Dann collection and is 4.5 inches long. This makes it probable that the later Iroquois derived their large beads, either by war or purchase, directly from the southern Indians, and not from white traders. The latter would hardly have brought unfinished articles to sell to the Senecas; and this may be part of the spoils of a war waged for a century. Beads of this kind were less used by the Mohawks and Oneidas than by the western Iroquois.

Fig. 116 and 117 represent two out of four polished cylindric

beads from Pompey, which are ornamented with encircling grooves. This is a rare feature in shell, though frequent in bone ornaments. Fig. 29 is a polished cylindric bead from Geneva.

There are many small beads aside from the common wampum. The oldest known closely resembling the modern wampum was found by the writer on the fort site west of Cazenovia in 1896. Fig. 261 represents this bead, which seems of Indian work, but possibly bored with metallic tools. The perforation is large, but nearly uniform. Fig. 81 shows another small, polished bead from this site, about double the length of the last, and also made from a small columella. Though the date of these is about 1600, A. D. they suggest some contact with Indians already having European tools. Fig. 260 is from Oneida Castle, resembling others except in its truncate form. Fig. 85 is elliptic in outline and comes from Munnsville. Fig. 259 is similar but more pointed. It is from Indian hill, Pompey. Fig. 258 was found by the writer at the same place, as well as fig. 82, which is constricted in the center, much like a dumb-bell. This was obtained in 1893. These five are all recent beads. Globular forms are found, but the council wampum was that commonly used. The next two are also recent. Fig. 265 is a fine angular form from the town of Venice. Fig. 267 is also angular, but quite flat. It is from the McClure site, Ontario county.

Runtees

Mr Holmes considers the large and familiar disks, so widely distributed, beads rather than pendants. He is correct in this, for several strings of these have been found just as they were deposited with the dead. The strings had decayed, but the ornaments were undisturbed. H. R. Schoolcraft described these in his *Notes on the Iroquois*, p. 233. He said of one kind, that "this article is generally found in the form of an exact circle, rarely a little ovate. It has been ground down and repolished, apparently, from the conch. Its diameter varies from $\frac{3}{4}$ of an inch to 2 inches; thickness, $\frac{2}{10}$ in the center, thinning out a little toward the edges. It is doubly perforated. It is figured on the face and its reverse with two parallel latitudinal and two longitudinal lines crossing in its

center, and dividing the area into four equal parts. Its circumference is marked with an inner circle, corresponding in width to the cardinal parallels. Each division of the circle thus quartered has five circles with a central dot. The latitudinal and longitudinal bands or fillets have each four similar circles or dots, and one in its center making 37. The number of these circles varies, however, on various specimens. In the one figured there are 52."

The form described by Schoolcraft is usually indented at the edge, where each perforation begins, and the cross lines are sometimes omitted. The small circles and dots have no meaning, the number being regulated by the space to be occupied. They were apparently made by a small circular steel drill, having a central point. The cross lines seem merely ornamental. As compasses were used in other forms, it is probable that these ornaments were made by white men for the Indian trade, and they may be the round shells used as presents in one New York council. The parallel holes from edge to edge served to keep the necklace flat when strung, and this feature is frequent in pipestone ornaments. These disks have been found in New England, New York, Ohio, New Mexico and many intermediate points, having been first used late in the 17th century. In New York they disappeared when silver ornaments came into fashion; and Mr Schoolcraft said that the Indians had no traditions concerning them. We are not in the dark, for their occurrence in graves shows their precise use and age. They had a later use westward. Lieut. Whipple procured a necklace in New Mexico in which were three of these ornaments.

Beverley, in his *History of Virginia*, p. 145, calls these runtees, and says "they are made of the conch shell, as the peak is, only the shape is flat and like a cheese, and drilled edgeways." Beverley wrote in 1722, when the Iroquois had generally abandoned these for silver ornaments, but they might be used longer near the seashore. While American in origin, the New York specimens were not aboriginal, nor can we assign them any early date in the matter of double drilling, which was continued in many of the recent ornaments of red slate and pipestone that succeeded them, or were contemporaneous.

Mr Schoolcraft gave this shell ornament the fanciful name of *nabikoáguna antique.* In continuation of the account quoted he adds some notes of value. "This article was first detected many years ago, in a medal, one and a half inches in diameter, found in an ancient grave on the Scioto in Ohio. . . Its occurence the present year in the ancient fort grounds and cemeteries of Onondaga, identifies the epochs of the ancient Indian settlements of Ohio and western New York, and furnishes a hint of the value of these investigations. A medium specimen was examined in the possession of I. Keeler, jr, Jamesville; another of the minimum size, at James Gould's, Lafayette. The largest specimen seen is one sent by J. V. H. Clark, from Pompey and Manlius." He adds that this ornament must be referred to the era preceding the discovery. Elsewhere he gives a figure of one from Sandusky, Ohio. The places to which he alluded above in Onondaga, under several names, were occupied in 1654 and 1696. In the next century many of the Iroquois went to Ohio to live, settling at Sandusky and near the Ohio river, where they carried their valued ornaments. Out of a large number of New York specimens a few examples are given.

Eight runtees from Pompey, which are in the Bigelow collection, are represented by reduced figures on one plate. Fig. 199 has but a trace remaining of the design. It shows plainly the brown matter adhering to the surface, and the frequent protuberance between the two holes. Fig. 199*a* shows circles and dots, and fig. 199*b* had the cross and dots. Fig. 201 is broken through one of the perforations, and has the frequent six-pointed star. This has also cross bars on the rays of the star, but they all slope, instead of being parallel with the outer circle, as is usual. Fig. 202 has also dots and circles, but is broken. Fig. 203 shows hardly a trace of the design. Fig. 205 has the star or flower divided in the usual way. Fig. 211 is also one of the larger ones showing rings and a star.

Fig. 147 is a small and plain one from Munnsville, which is less circular than most, though but few are exact in this way. One broad indentation on either side of the border shows where the holes are. Fig. 146 is a pretty example from Cayuga county, with

the cross, circles and dots. Fig. 253 is also from a recent Cayuga grave, in which several were found of rather rude character. In this the dots are irregularly disposed. Fig. 253*a* is from the Onondaga site of 1696. As it is thinner than usual, and shows no ornament, it may have been worn down. Both these are reduced in the plate. Fig. 148*a* is from Pompey, having a design of large and small circles. Fig. 143 is ornamented with a cross of small circles, and comes from the Dann farm, Honeoye Falls. Fig. 161 has concentric circles and two rows of dots. It is from the McClure farm, and belongs to Irving W. Coats, of Shortsville (N. Y.) who has many specimens. The most remarkable form of all is shown in fig. 138, from the Onondaga fort of 1696. In outline it is symmetric, but much like the early banner stones. Fig. 156, 157, 158 and 159 are common forms from Pompey. Fig. 157 has more points than usual. Fig. 160 is one of a number in the state collection, found together in Ontario county. It has the rare feature of a deer in the center.

One remarkable example of the runtee is in the Toronto collection, and is represented in the *Annual archaeological report* for 1897-8 by fig. 30. It has not the cross, but three concentric circles have been described with compasses from the center of the circular shell. Two rows of small circles and dots are on either side of the middle circle, which were evidently made with a metallic tool. From eight points near the edge of the disk two half circles have been swept, and outside and inside of the outer line are extremely small circles or large dots following its curve. There are the usual indentations of the edge where the two perforations occur. It is about 2 inches in diameter. David Boyle, in describing this said: "The three concentric circles in the middle and the arcs on the margin have been described from central points by means of something answering the purpose of compasses, as have also the smaller circles surrounding the dots. The pattern has been carefully laid out and as accurately worked out." It may be added that the various ornaments on a series of these articles, show plainly the use of compasses. This one was found in the old Huron country, and their general distribution makes it possible that they were of French rather than Eng-

lish or Dutch manufacture at first. Those made by the Virginia Indians were almost an inch across and one third of an inch thick, illustrating the advantage of better tools in making larger ornaments by their comparative rudeness

Other articles

Pendants. Pendants made from spiral shells are not common. Fig. 15 is of one found on a village site near Baldwinsville by the writer, and closely resembles one from Florida, figured as a sinker, by Dr Rau. The outer whorl has been cut away and the lip notched. A groove has also been made for suspension. Fig. 16 has been worked still more, forming a groove at each end. This is from Brewerton. Fig. 12 is less changed, but is perforated at the base for suspension. It was found by Dr A. A. Getman of Chaumont, at a camp near St Lawrence village. All these are prehistoric, but the first may be 350 years old. Fig. 28 is of a fossil bivalve from Seneca county, and the beak is perforated for suspension. Fig. 114 is an olive shell pierced for use. This and a much larger one were found in a stone grave near Beaver lake, a little west of Baldwinsville. Three large spearheads were with them, and all must have been quite old. Fig. 124 is a disk pendant from Honeoye Falls. Fig. 44 to 56 are mostly pendants figured in Schoonmaker's *History of Kingston.* They are probably reduced, and may have been about the size of two similar articles in fig. 166 and 168, which are from Honeoye Falls. Fig. 149*a* is a pendant from the Onondaga fort of 1696, as given by Schoolcraft. Fig. 144*a* is a doubly perforated and grooved ornament from Honeoye Falls, and was probably a pendant. Fig. 80 is from Cayuga, and its use is more doubtful. Most of the 10 countersunk indentations end in a small perforation, and it is also grooved. Fig. 64 is a shell cross from Pompey. There are dots at the ends of the arms, and others in the form of a cross. These were encircled with small rings, now worn away. It is in the Bigelow collection.

The Cayugas used pieces of turtle shell for pendants. Fig. 148 and 149 are of that material, and came from Union Springs. Fig. 153 has but one perforation instead of two, and was found with

others south of Genoa village. Fig. 154 is a young turtle shell, neatly perforated, which came from one of the earliest Mohawk villages, the one in Ephratah.

Fig. 23 and 24 came from a cache of chipped shells otherwise unworked, found in Lindley, Steuben co. All were pieces of marine bivalves and of about the same size. They may have been intended for either pendants or disk beads. This is the only cache of the kind reported. Fig. 140 is of a neatly cut shell from Brewerton, designed for some unfinished ornament. Fig. 264 is a pendant from the town of Venice, somewhat cordate in form. Fig. 142 may be an unfinished pendant, now unperforated. It is from Honeoye Falls.

Rings. Bronze rings were so abundant that few were made of shell. Fig. 144 shows a fine signet ring from Cayuga, and fig. 51 and 52 smaller and plainer ones from Ulster county.

Masks. Masks were usually of stone or bone, but Mr Tooker has a small shell mask from Sag Harbor. Fig. 139 is from one given by Schoolcraft, and found at the Onondaga fort of 1696. Fig. 126 is larger, and is in the Dann collection. It is of about the age of the last.

Pins. W. H. Holmes, on page 213 of *Art in shell*, speaks of the pins fashioned from the columellae of large seashells as requiring much labor and skill. In his experience three fourths of these were made from the Busycon perversum, and Tennessee was the great storehouse for these and other ancient articles of shell. These pins are quite rare in New York, and those thus far found are of the latter part of the 17th century. Two are here figured which came from a recent village west of Honeoye Falls, supposed to have been occupied by the Senecas about the time of De Nonville's invasion in 1687. It affords abundant European articles, council wampum, bone combs and shell ornaments. These pins are shown in fig. 78a and 79. In examining them the writer did not identify the shell or part of the shell used in the second pin, as it was so much worked as to obliterate any striking features. The first is of Busycon. Nothing of the kind has been reported from any earlier site; and these may be the trophies of some Seneca

war party, gained from a southern tribe. The point of importance is that these shell pins were in use after the New York colony passed into English hands. One curious pin in the Toronto collection has some features of a remarkable shell article in Mr Dann's collection at Honeoye Falls, but the former was evidently a pin, while the use of the latter is doubtful. Fig. 145 shows this, which is much in the form of a short-handled ladle. The perforation suggests a suspended ornament.

Knives. The shells of Unio complanatus are abundant on some early Iroquois sites, being the favorite species for food, and occasionally one has been perforated. The writer found a shell of Unio rectus on an Oneida site, nearly 30 miles from where the mollusk lived, and this might have made a good knife but showed no signs of use. It is certain such shells were used in this way, but they needed little preparation. A captive to the Iroquois in 1639, secretly "picked up a shell which she found on the strand, put it away without saying a word, and in the night, every body being asleep, she softly cut her bonds with this shell, and fled away by stealth into the forest."—*Relation*, 1639

The *Relation* of 1647 has a full account of Father Jogues, including his first captivity among the Mohawks in 1642. After his left thumb had been cut off, the missionary adds, "they used a shell or an oyster shell (*d'vne coquille ou d'vne escalle d'huitre*) to cut off the right thumb of the other Frenchman, in order to cause him more pain." Jogues seems in doubt as to the kind, and probably gave little heed to this in his sufferings. An oyster shell would hardly have been looked for so far up the Mohawk river, and, as the river was less than a mile away, it was probably one brought to the village for food. The incident shows that the use of shells as knives was familiar.

Kalm, in his *Travels into North America*, 1772, 1 : 341, says that the Indians of New Jersey used some sharp and hard stone for a knife, or were satisfied "with a sharp shell, or with a piece of bone which they had sharpened." The Indian feast prepared far up the river for Henry Hudson is well known. Among other palatable things they "killed a fat dog, and skinned it in great haste with shells

which they had." These were picked up anywhere, and were naturally sharp enough for most purposes, but occasionally some alteration may be detected. A few such examples are in the Toronto collection, which seem to be scrapers.

But one article directly suggesting a shell knife has come to the writer's notice in New York, and this is in Mr Hildburgh's collection. Fig. 87 represents this. The perforated Unio rosaceus from the Waterburg fort, shown in fig. 11, may have been either knife or ornament. The same may be said of the perforated Unio complanatus, fig. 13, from a site near the Mohawk river. Bivalves were also used as tweezers, in extracting hair; and large shells were employed as hoes.

Gorgets. After speaking of the runtees or small disks, Beverley (p. 196) describes a larger article, saying: "Of this shell they also make round tablets, of about 4 inches in diameter, which they polish as smooth as the other, and sometimes they etch or grave thereon circles, stars, a half moon, or any other figure suitable to their fancy. These they wear instead of medals before and behind their neck." About the beginning of the 18th century the English began giving silver medals to the Indians of New York, and the shell gorgets almost disappeared. The southern Indians, being of less account, got no medals for a long time.

Lafitau, in his *Moeurs des sauvages Ameriquains,* p. 61, said: "The collars which the savages sometimes wear around the neck are about a foot in diameter, and are not different from those which one now sees on some antiques, or the necks of statues of barbarians. The northen savages wear on the breast a plate of hollow shell, as long as the hand, which has the same effect as that which was called *bulla* among the Romans." Kalm, in his *Travels into North America,* 1772, 2:320, after describing the shell beads of the Hurons near Quebec, adds that some "have a large shell on the breast, of a fine white color, which they value very high and is very dear." It is possible that the shells, mentioned with the wampum pipes and round small shells as English presents for the *Dionondadies* in 1702, may have been something of this kind, as shell gorgets were then used in New York, and a few survive.

An Indian model in the national museum shows how these gorgets were worn, with the concave side outward. A string or knotted cord, drawn tight through the holes, would keep them in position, and it is probable that the stone gorgets were similarly fastened to the clothing as ornaments. Mr Holmes figured (pl. 50) a large, keystone-shaped shell gorget of the historic period, from an ossuary of the Neutrals in Canada West. It has four holes and the four edges are slightly convex. The number of holes varies much. In New York such gorgets may be either of bone or shell. They were too conspicuous to be easily lost, and their number is not large. All which are made of shell are recent, but some of bone are earlier. They are either plain or very slightly ornamented as compared with those of Tennessee, which often have fine carvings and grotesque groups suggestive of Mexican work, and even of Buddhist mythology. A few Canadian shell gorgets in the Toronto collection are also plain, and two of these are very long. In the report of that collection for 1899 is a fine engraved one, which has been recut and is now half the original size, being now 4.5 by 2 inches. At first it was oval, but one side is now straight, and two holes are near this and two more near the convex margin.

Fig. 208 is a reduced figure of the largest shell gorget yet reported in New York. It is in the Bigelow collection and came from Pompey, being made from the outer whorl of a large shell. The diameter is 5.25 inches. The shell was dead and somewhat eaten, which may account for its lack of ornament. There are two small perforations. Fig. 209 is a much smaller one from the same town, which has been much corroded since it was used. It is over 3 inches wide, and has two nearly central holes, with another begun between them. The inner ornaments are circles, points and dots, with some indefinite grooves on the convex surface. Fig. 155 produces this in full size, to show more clearly the interior design. There have been vague reports of other engraved shells in that town, but as far as the writer knows this is the only engraved shell gorget yet found in New York. Morgan figures a later form. Those described below are of actual size.

Fig. 122 is a plain gorget from Mapleton, or East Cayuga, hav-

ing three holes and the beginnings of two more. Fig. 128 is of rather large size, of a generally elliptic form, and one long edge is nearly straight. On the other edge two holes approach the margin. This and the next are from Venice. Fig. 123 has a pyriform outline and two perforations. It is smaller than the last. Fig. 165 is a fine one from Cayuga, half an inch deep and having one hole. Fig. 163 is of an oval form, with two holes at the broad end, and comes from Pompey hill. All Onondaga specimens seem of the 17th century, but some may be later.

These were not rare on the modern site on the Dann farm, near Honeoye Falls. Fig. 162 is the largest found there, being 3.3 inches across. It has two sloping holes, the slope possibly coming from use. These are quite far apart, and there may have been a third where a piece of the shell has been lost. Fig. 164 is from the same place, has two large holes, and is 1.9 inches wide. Fig. 164*a* also belongs to this site and is 2.15 inches long, being about as irregular as the last, though nearly circular. It has two very small holes, quite close together. Another from this place is of about the same form and size, but is unperforated. These four are in Mr Dann's collection. Fig. 210 is also unperforated, but is of very neat workmanship, and is in the Bigelow collection. Like all others it was made from the whorl of a large shell, and is somewhat elliptic in outline. In the figure it is reduced, being 1.6 inches long. It was found near Baldwinsville. The actual size appears in fig. 167.

These sufficiently represent the ordinary shell gorgets of New York, all but one reported being plain. There are similar but smaller ornaments of turtle shell.

It may be added that Joseph Brant's large shell gorget was long preserved in his family, and that there is an old picture of him with this attached below the throat. It had two holes for this purpose, and was quite like those used by the Onondagas in recent times.

Miscellaneous

From M. R. Harrington, by kind permission of Prof. F. W. Putnam, has come an account of the aboriginal shell objects in the American museum of natural history, in Central park, New York.

A note said, "The museum's collection of local shell objects is very small, though there are several specimens of the classes shown in nos. 3, 4, 6, 7 and 9." The list was accompanied by photographs of the articles, and is quoted in full, with some comments by the writer.

"1 Carved Unio shell from ancient rock shelter near Armonk, Westchester co. N. Y." This has been cut into a long pentagon, in the upper part of which is a slightly elliptic and neat indentation, nearly an inch across. Part of another appears on the narrow margin below, making it probable that the ornament has been broken and cut down. Its character suggests the use of metallic tools.

"2 Scraper of oyster shell from another shelter in the same vicinity." This is quadrilateral and well worked.

"3 Broken shell pin or awl from shell heap in Pelham Bay park, N. Y. city." A long and rude article, apparently a pin.

"4 Two shell beads from ancient grave at Tivoli on the Hudson. Copper beads were also found." These are short cylindric beads, with the diameter greater than the length, and are of an antique type which came down to very recent times.

"5 Oliva shell, with spire broken to facilitate use as bead. Shell heap in Pelham Bay park, N. Y. city." Much weathered, and with lateral perforation. It is a southern shell.

"6 Five Olivella shell beads. Part of a lot numbering more than 100, found in ancient grave at Tottenville, Staten Island. With copper stains." One of the five is Nassa obsoleta; another seems to be Littorina rudis; both local species. The other three are Marginellas from the south.

"7 Perforated oyster shell from prehistoric village site at Port Washington, L. I." A large and rude perforation.

"8 Implement of oyster shell from ancient fire pit at same place." This resembles a long and rude awl.

"9 Perforated shell of Busycon carica, Gmelin, found buried with a dog in a fire pit at same place." A large perforation in the outer whorl. The base has been cut off, and nodules ground down.

"10 Clam shell (mercenaria) used as a scraper. From

ancient village site at Van Cortlandt park, N. Y. city." Lower margin battered.

"11 Worked clam shell (mercenaria) possibly a spoon. From ancient shell heap at Throggs neck, N. Y. city." The upper and anterior margins are both cut down; the latter very much so. The unworked form would have been as serviceable as a spoon, but it may have been used in this way. It may be added that marine shell heaps are of very uncertain age, white men often feasting on those begun centuries before.

Wampum keepers

In discussing wampum at another time the writer had occasion to speak of Mr Morgan's statement in the *League of the Iroquois*, p. 65, where he says that *Ho-no-we-na-to*, of the Onondaga Wolf clan, was hereditary keeper of the wampum. Captain George, who long bore this principal chief name, never had anything to do with the belts. Thomas Webster, or *O-ya-ta-je-wah*, who held them till his death, was a Snipe. Abram La Fort, or *Te-at-gah-doos*, from whom he received them, was a Bear. John Buck, or *Skan-a-wah-ti*, the Onondaga Canadian wampum-keeper, was a Turtle. David Zeisberger was adopted into the Onondaga Turtle clan in 1745, and the keeper of the wampum thus became his foster brother. At a later day Zeisberger kept the wampum himself. The truth is, it was a question of convenience and ability. Even at the time Morgan wrote, *Ho-no-we-na-to* did not keep the belts, nor have his several successors held them.

In regard to belts belonging to the confederacy, the Onondagas were the keepers as a matter of convenience, but they did not control those belonging to other nations. These gave, received and kept belts as they pleased. Of late it has been supposed that there were wampum-keepers for both the Elder and Younger Brothers as bodies, but the writer knew well both the reputed keepers, and there seems to have been but one recognized office of the kind. Many Indians long had wampum of their own, and a few have a little even now.

Conrad Weiser made a quaint note, July 20, 1747, about a Del-

aware chief: "*Olumapies* would have Resigned his Crown before now, but, as he had the keeping of the public treasure [that is to say, the Counsel Bagg] Consisting of Belts of Wampum, for which he buys Liquor, and has been Drunk for this two or three years, almost Constantly, and it is thought he wont Die, so long as there is one single wampum left in the Bagg."—*Penn.* 1:762

Weiser made another note at Onondaga, Sep. 16, 1750, which shows that the wampum-keeper was probably not restricted to a single clan. *Canassatego* had died, being the speaker but not the *To-do-da-ho,* or head chief. "I was told by *Tahashronchdioony,* the Chief, that all the Belts of Wampum belonging to the Publick from the several English Governors that remained unanswered at the Death of *Canassatogo,* and found in his Possession, were by his orders burned[1] with him. This the said Chief said to make *Canassatogo* a Thief after his Death; some imagine that his Widow and Family took them."—*Penn.* 5:480

In this case it is probable that the Onondaga speaker held the belts till they were accepted, after which they would be divided or retained according to the action of the council. It should always be remembered that even in the grand council belts might be given to any one nation, and retained by it.

Belts

Making. The accounts we have of the making of early belts are conflicting, leading us to suppose they were not all alike. In his *Narrative of the Indian wars in New England* Hubbard says: "They are woven as broad as one's hand and about 2 feet long. These they call belts, and give and receive at their treaties as seals of their friendship." Loskiel says, p. 26: "Four or six strings joined in one breadth and fastened to each other with fine thread, make a belt of wampum, being about 3 or 4 inches wide and 3 feet long, containing perhaps four, eight or twelve fathom of wampum, in proportion to its required length and breadth. This is determined by the importance of the subject which these belts are intended either to

[1] The word burned in Weiser's account was evidently intended for buried.

explain or confirm, or by the dignity of the persons to whom they are to be delivered." Though belts might be made in this way, they would not have the width mentioned, as six strings laid side by side would not give a breadth of one inch. Lafitau's account is better. "The belts are large bands, in which little white and purple cylinders are disposed in rows, and tied down with small thongs of leather, which makes a very neat fabric. . . The usual belts are of eleven rows of 180 beads each." Carver said: "Being strung on leather strips and several of them sewed neatly together with fine sinewy threads, they then compose what is termed a belt of wampum." This is reversing the mode, as no strip of leather would pass through the small aperture. Yet Charlevoix gave much the same account in his 13th letter, in describing branches and collars. "The branches are no more than four or five threads or small straps of leather, about a foot in length, on which the grains or beads of wampum are strung. The collars are in the manner of fillets or diadems formed of these branches, sewed together with thread, making four, five, six or seven rows of beads, and of a proportionable length; all which depends on the importance of the affair in agitation, and dignity of the person to whom the collar is presented." This seems far from the truth.

In his *League of the Iroquois*, L. H. Morgan said:

"Belts were made by covering one side of a deerskin belt with these beads, arranged after various devices and with most laborious skill." No such belts are known, but it is probable that the early quill belts were of this nature, if their existence is allowed.

Mr Morgan gave a better account the following year, when he said: "The most common width was 3 fingers or the width of 7 beads, the length ranging from 2 to 6 feet. In belt-making, which is a simple process, eight strands or cords of bark thread are first twisted from filaments of slippery elm, of the requisite length and size; after which they are passed through a strip of deerskin to separate them at equal distances from each other in parallel lines. A splint is then sprung in the form of a bow, to which each end of the several strings is secured, and by which all of them are held in tension, like warp threads in a weaving machine. Seven beads, these making the intended width of the belts, are then run upon a thread by means of a needle, and are passed under the cords at right angles, so as to bring one bead lengthwise between each cord

and the one next in position. The thread is then passed back along the upper side of the cords, and again through each of the beads; so that each bead is held firmly in its place by means of two threads, one passing under and one above the cords. This process is continued until the belt reaches its intended length, when the ends of the cords are tied, the end of the belt covered and afterwards trimmed with ribbons. In ancient times both the cords and the thread were of sinew.

This is a good account in general of the making of the belt prepared for Mr Morgan at Tonawanda in 1850, and shown in fig. 241, but it has decidedly modern features. In most of those seen by the writer the long strands were of buckskin and the edges neatly braided or twisted. Common twine was sometimes used, but no ribbons. The simple mode described of placing the beads is correct.

Loskiel, p. 27, said that "the Indian women are very dexterous in weaving the strings of wampum into belts, and make them with different figures perfectly agreeing with the different subjects contained in the speech." An instance appears in the report of the council in Easton in 1756, which was concluded before one important belt was ready. "Here the Governor gave the new belt as far as it was made, and all the wampum prepared for it." He explained the proper figures "& desired the women might finish it on rainy days, or resting in their Journey."—*Penn. Minutes*, 7:218

White men sometimes made belts. In the journal of John Hays it appears that he was at Wyoming, May 13, 1760. Being detained there by bad weather, he "wrought at Makeing Belts and Strings of our Wampum." He also made these entries: "14th. Very Rainy Wether, so that we Could not set out, So we followed our old Business of Belt making." "15th. Wether the Same, so that we wer Oblidged to Ly by as Before and Mad Belts."—*Penn.* 3:735. But for the unwelcome rain, we might not have known of this.

On the whole it is probable that many early ornamental belts and collars were differently made from those which now remain. They may have been much like those examples of mere ornament from our own and other lands to be seen in our national museum, neatly arranged in patterns but in several different ways. For some of these a variety of sizes might produce the best effect. Sometimes

the early writers give hints of this diversity, but in general any thing about the body was a belt, anything around the neck a collar. They used comprehensive terms. Thus when we are told that the Hurons bet collars of porcelain on the game of lacrosse in 1636, we need not think of the wampum belts we have seen. When the *Nipissiriniens* six years later gave presents of collars and scarfs of porcelain at their feast of the dead, both may have been made of large shell beads. They probably were, as the small council wampum was not showy, but made with a definite end in view.

These remarks apply to the famous dress of King Philip. In the account of his death quoted by S. G. Drake, in his *Biography and history of the Indians of North America*, 1:54-55, we are told that *Annawon* "took out of his pack a beautifully wrought belt which belonged to Philip. It was 9 inches in breadth, and of such length as, when put about the shoulders of Captain Church, it reached to his ankles. This was considered at that time of great value, being embroidered all over with money, that is wampum peag, of various colors, curiously wrought into figures of birds, beasts and flowers. A second belt of no less exquisite workmanship was next presented, which belonged also to Philip. This the chief used to ornament his head with, from the back part of which flowed two flags, which decorated his back. A third was a smaller one, with a star upon the end of it, which he wore upon his breast. All three were edged with red hair, which *Annawon* said was got in the country of the Mohawks." These belts evidently had a foundation on which curious patterns were embroidered with shell beads.

Josselyn's description also conveys the same idea. It will be found on pages 142-43 of his *Account of two voyages to New England*, with kindred matter.

Their beads are their money, of these there are two sorts, blew Beads and white Beads; the first is their Gold, the last their Silver, these they work out of certain shells so cunning that neither *Jew* nor Devil can counterfeit, they dril them and string them, and make many curious works with them to adorn the persons of their *Sagamours* and principal men and young women, as Belts, Girdles, Tablets, Borders for their womens hair, Bracelets, Necklaces, and links to hang in their ears. Prince *Phillip*, a little before I came for *England* [1671] coming to *Boston*, had a coat on and Buskins set

thick with these Beads in pleasant wild works, and a broad Belt of the same, his Accoutrements were valued at Twenty pounds.

This was embroidery, much like modern Indian beadwork, and appears in early pictures of King Philip.

That council belts were much the same as now at an early day will appear from fig. 282, a reproduction of La Hontan's picture of De la Barre's council at La Famine in 1684. It is from the second English edition, published in 1735. Fig. 255 also represents an early belt of 1711, taken from the picture of "*Fee-yee-neen-ho-ga*, Emperor of the Six Nations," painted from one of the four Mohawks then in England. The belts are like those of the present day.

Reading. Heckewelder, p. 107-8, gives an interesting account of the periodical reading of wampum.

For the purpose of refreshing their own memories, and of instructing one or more of their most capable and promising young men in these matters, they assemble once or twice a year. On these occasions they always meet at a chosen spot in the woods, at a small distance from the town, where a fire is kindled, and at the proper time provisions are brought out to them. There, on a large piece of bark or on a blanket, all the documents are laid out in such order, that they can at once distinguish each particular speech, the same as we know the particular contents of an instrument of writing by the indorsement on it. . . Their speaker then, who is always chosen from among those who are endowed with superior talents, and has already been trained up to the business, in an audible voice delivers, with the gravity that the subject requires, the contents, sentence after sentence, until he has finished the whole on one subject. On the manner in which the belts or strings of wampum are handled by the speaker, much depends; the *turning* of the belt which takes place when he has finished one half of his speech, is a material point, though this is not common in *all* speeches with belts; but when it is the case, and is done properly, it may be as well known by it how far the speaker has advanced in his speech, as with us on taking a glance at the pages of a book or pamphlet while reading; and a good speaker will be able to point out the exact place on a belt which is to answer to each particular sentence, the same as we can point out a passage in a book. Belts and strings, when done with by the speaker, are again handed to the chief, who puts them up carefully in the speech bag or pouch.

In describing the use of one by the Indians and Sir William Johnson, John Long said that it was of many rows, black at the sides and white in the middle. This signified the path of peace, and

a white diamond in the center the council fire. In reading it, the baronet held one end and the Indian chief the other. When the latter spoke, he moved his finger along the white line. When Sir William spoke, he touched the diamond in the midst of the belt.

Heckewelder, p. 109, treats quite fully of the colors and emblems of belts, and adds something on wampum as credentials, a character which still survives. "No chief pays any attention to *reports*, though they may carry with them the marks of truth. . . But as soon as he is officially informed, through a string of wampum from some distant chief or leading man of the nation, whose situation entitles him to receive credit, he then will say, 'I *have* heard it,' and acts accordingly."

In the *Relation* of 1653, p. 27, we are told how a New England chief had his presents spread out, which were mostly of wampum. Standing by them, "he gave the explanation of them as one would do of an enigma, touching the characters on the picture one after another." Each had its proper meaning.

Loskiel's account, p. 26, is much like that of Heckewelder.

At certain seasons they meet to study their meaning, and to renew the ideas of which they were an emblem or confirmation. On such occasions they sit down around the chest, take out one string or belt after the other, handing it about to every person present, and that they may all comprehend its meaning, repeat the words pronounced on its delivery in their whole convention. By these means they are enabled to remember the promises reciprocally made by the different parties; and it is their custom to admit even the young boys, who are related to the chiefs, to their assemblies; they become early acquainted with all the affairs of the state; thus the contents of their documents are transmitted to posterity, and can not easily be forgotten.

For a long time this practice has been discontinued, and the belts were only produced to satisfy curiosity. In most ceremonies strings alone were used, and the knowledge of the proper use of some of these was and is confined to a few persons. Horatio Hale's picture of the reading of the wampum belts was one arranged for his convenience and pleasure, not a record of an ordinary occurrence. In fact treaty and war belts had nothing to do with modern ceremonial gatherings.

Lettered. Belts with letters on them obviously had a civilized origin, and were often made by Indians to whom the design was given. Animated by religious zeal, and naturally liberal in their gifts, the poor Huron exiles near Quebec devised such a belt in 1654. It was an offering to the Virgin Mary by the first congregation of Notre Dame in the Huron colony. They had small means, but collected several hundred beads and formed of these a belt. On a ground of white wampum black beads made the words *Ave Maria gratia, plena*. This was accompanied by a Huron letter on birch bark, dictated by the Indians and written by the priests. Both were sent to Paris, where later belts found their way. The same colony sent a belt to Chartres cathedral in 1679, which was 4 feet 9 inches long, and 2.75 inches wide. On a foundation of white beads were black letters reading *Virgini pariturae votum Huronum*. This belt was bordered with embroidery of red porcupine quills.

The writer of the *Relation* of 1683-4 was enthusiastic over the *Abenakis* mission, in the chapel of which was a figure of St Francis de Sales:

> There was placed below the image of the saint a very large porcelain collar, adorned with porcupine quills. . . It is the most beautiful collar I have seen made here. . . Tall Jeanne, who made the whole collar and colette, who set the porcupine quills in it, has done so with a great zeal of honoring the saint. The inscription on the collar is: *S. franc salisio Abnaq. D.* (*Sancto francisco salisio Abnaquiis Donatum*).

W. L. Hildburgh has furnished the writer with descriptions and sketches of some wampum belts in Europe. Of one in the museum of the Propaganda in Rome little could be learned. Four are in the Trocadero palace in Paris, all of which are Huron. One is 12 beads deep and about 200 long, but is broken at both ends. The black letters on the white ground read, VIRGIN. IMMAC. HVRD. D. This has been figured in *Gallerie Americaine du musée ethnographie du Trocadero*, with three others. Fig. 271 shows this as drawn from the photograph by Mr Hildburgh.

A small number of lettered belts appeared in the English colonies much later. Gov. Burnett gave one to the Six Nations at Albany in 1724, on which were the letters G. R., for King George. An-

other had G. P. W., for George, Prince of Wales. A third had P F., for Prince Frederick. A more striking example is that of the great belt given at Easton by the governor of Pennsylvania in 1757. Peace had been concluded with *Teedyuscung* and the Delawares, and the Five Nations had approved of the terms, having sovereign power over the Pennsylvania Indians. In confirmation of the treaty Gov. Denny "gave a very large belt with the figures of three men in it, representing His Majesty King George taking hold of the 5 Nations King with one hand, and *Teedyuscung* the Delaware King with the other, and marked with the following letters and figure: G. R. or King George 5 N five Nations and D. K. Delaware King." A curious belt was shown by *Teedyuscung* a little before this. It was "a Short, broad Belt of White Wampum, having in the Center two Hearts of a Reddish Colour, and in Figures, 1745. . . The Belt had a round Circle Pendant, representing the Sun."—*Penn. Minutes*, 8:217. This ornament may have been a flat, metallic ring. The belt was given to the Wappingers by the government of New York. Between the numerals 17 and 45 were two small ornaments. One other belt must have been inspired for the occasion. Preparations for the siege of Fort Niagara were in progress, and Johnson held a council. At this the Six Nations presented him "a Belt with the Figure of Niagara at the end of it, & Sir William's name worked thereon." Of course the baronet thanked them and expressed his satisfaction at their readiness for the work. This was in 1759, and Fort Niagara soon fell. Belts of this character were not common, the Indians preferring symbolic figures, such as they had known from early days. Another of Johnson's lettered belts is elsewhere mentioned, and also one probably presented by Gov. Simcoe, now in the national museum. This appears in fig. 269.

Emblematic. The earliest emblematic belt of which we have any distinct account was presented at Quebec in 1653 by an Indian chief from New England. He spread this out saying:

"This is the road that it is necessary to keep in order to come to visit your friends." The collar was composed of white and violet porcelain, so that there were some figures which this good man ex-

plained in his fashion: "There," said he, "are the lakes, here are the rivers, here are the mountains and the valleys that it is necessary to pass. Here are the portages and waterfalls."—*Relation*, 1653. He had meanings for all his other belts but they contained no figures.

There has been a disposition to consider an existing Onondaga belt as one presented by Chaumonot in 1655, but there is little ground for this. Had the one he gave at that time contained such figures, they would certainly have been described. It happened that Father Le Moyne went on an embassy to the Mohawks in the autumn of that year, and was warmly greeted by them. He was at once received with three belts and the next day had other rich presents. "The first and most elaborate of these presents was a large figure of the sun, wrought with 6000 beads of porcelain, to the end, he said, that darkness may have no place in their councils, but that the sun may shed his light upon them even in the night." This is not expressly called a belt, but was probably of that nature and wrought in some convenient form.

Very few of these strictly emblematic belts were described in the 17th century. One belt received at Oneida from the French, while Father Milet was a captive there, brought a response which stirred up the colonial authorities. The Five Nations called Milet to Onondaga to write down the message they wished to send to Frontenac with three belts. "The 1st in which there are five black squares on a white ground, indicates the Five Iroquois Nations, who have all unanimously agreed to this embassy from the Iroquois to Kebec. They, therefore, say by this belt: Here we are, Father Onontio, by your invitation, on your mat." Rev. Mr Dellius translated this for Gov. Fletcher, and the commotion subsided. In 1690 the last of 13 belts presented by the Five Nations at Albany had also the five houses on it. It is probable that the Onondaga covenant chain belt of 1682 was emblematic, but no figures are described.

There were frequent quarrels with traders, and the Iroquois often made stringent rules against the introduction of strong drink into their towns. In 1721, many years after they had conquered the Indians of Pennsylvania, "the five Nations had sent down a large Belt of Wampum with the figure of a Rundlet and an Hatchet on

it, to the Indians settled upwards on Susquehanna, with orders to stave all the Rum they met with."—*Penn. Minutes,* 3:154. This vigorous order brought trouble. At Staunton in the same state, in 1736, a white belt of eleven rows had "four black St George's crosses in it."—*Penn. Minutes,* 4:83

A supposed earlier emblematic belt, suggestive of a later date, was seen by Conrad Weiser at Logstown in 1748. He was told that it was given to the Wyandots by the governor of New York 50 years before; and if this could be proved, it might sustain the antiquity of the Penn belt, which has a similar character. Of the one in question Weiser said:

> The Belt was 25 Grains wide & 265 long, very Curiously wrought. There were seven Images of Men holding one another by the Hand, the 1st signifying the Governor of New York (or rather, as they said, the King of Great Britain) the 2d the Mohawks, the 3d the Oneidas, the 4th the Cajugas, the 5th the Onondagers, the 6th the Senekas, the 7th the Owandaets, and two Rows of black Wampum under their feet, thro' the whole length of the Belt to signify the Road from Albany thro' the 5 Nations to the Owendaets; That 6 years ago they had sent Deputies with the same Belt to Albany to renew the Frienship.—*Penn. Minutes,* 5:351

The writer finds no records of this later visit. Some Wyandots came to Albany in 1702 to trade, and in the same year a belt was sent to them, possibly this one, but there is no allusion to its character. Some were there in 1723, and received presents but no belts. Allowing the possible identity of the belt, it is strange that the emblems had little use for half a century later. Even then its date would be 20 years later than Penn's first contact with the Indians. It seems better to assign the Penn belt to his second visit at least. Mr Holmes said that "it has an extremely interesting, although a somewhat incomplete history attached to it. It is believed to be the original belt delivered by the *Leni-Lenape* sachems to William Penn at the celebrated treaty under the elm tree at Shackamaxon in 1682. Although there is no documentary evidence to show that this identical belt was delivered on that occasion, it is conceded on all hands that it came into the possession of the great founder of Pennsylvania at some one of his treaties with the tribes that occupied the province ceded to him. Up to the year 1857 this belt

remained in the keeping of the Penn family. In March 1857, it was presented to the Pennsylvania historical society by Granville John Penn, a great grandson of William Penn."—*Holmes*, p. 253-54. So much for its history. In his address on its presentation Mr Penn said its dimensions were greater than those used on ordinary occasions, being 18 rows deep, that the two figures clasping hands signified a treaty, that one of these wears a hat and must be a European, and that its long continuance in the family leaves no doubt of its genuineness. The last is the only strong point. It is a fine but moderate sized belt of less than 3000 beads, shown in fig. 173, and many larger and wider ones are on record in unimportant councils. A treaty is signified, but the supposed hat appears as an undoubted Indian's head on another belt, where similar figures are seen joining hands. Aside from its history there would be no hesitation in placing it in the middle of the 18th century, to which both figures and sloping lines belong. Besides its preservation two other points in its favor may be mentioned. One of these is the relative proportion of purple and white beads, though the Onondaga-United States covenant belt is of the same character in this and other things. The other is that Conrad Weiser described a similar belt in 1748, as already stated, which he was then told belonged to the end of the preceding century. Evidently the Penn belt had never been shown him. However these facts may affect its history incidentally, there can be little doubt it is the oldest wampum belt but one now in America, and it may well be prized as such.

Fig. 171 shows an earlier belt now in the county clerk's office in Kingston (N. Y.) of which a small picture appears in the *History of Kingston*, by Marius Schoonmaker, p. 40. It was given by the Esopus chiefs at a treaty in 1664, and is laid up with the record. There are three gaps in it, and it has no pattern, being made entirely of white beads. It is six rows deep and about 130 beads long.

The style of belts of which the Penn and the Onondaga covenant belt are among remaining examples became somewhat frequent about the middle of the 18th century. The supply of wampum and the use of belts seem to have lessened for a time, but revived won-

derfully under Sir William Johnson. He used both strings and belts with a lavish hand, multiplied emblems and ceremonies, and gave precision to many that were indefinite before. Union, chain, covenant, road, invitation, peace, war, scalp and other belts frequently appear. Belts became as abundant as they were a hundred years before, but often with new names. This pleased the Iroquois greatly, and they often thanked him for reviving their ancient ceremonies. There can be no question that these enlarged under his wise direction.

In his interesting letter to Arthur Lee in 1771, Johnson gives a few particulars regarding belts, of which he had handled and explained hundreds. He said:

As to the information wch you observe I formerly Transmitted to the Gov[r] of N. York concerning the belt & 15 Bloody Sticks sent by the Mississagaes, The like is very Comon and the Ind[s] use Sticks as well to Express the alliance of Castles as the number of Individuals in a party, These Sticks are generally ab[t] 6 Inches in length & very slender & painted Red if the Subject is War but without any peculiarity as to Shape. Their belts are mostly black Wampum, painted red when they denote War, they describe Castles sometimes upon them as square figures of White Wampum, & in Alliances Human figures holding a Chain of friendship, each figure represents a nation, an axe is also sometimes described wch is always an Emblem of War, The Taking it up is a Declaration [of war] and the burying it a token of Peace.

There are other valuable observations on emblems used in other ways, as well as on language and customs in this letter, which will be found in the fourth volume of the *Documentary history of the state of New York.*

In 1756 the Six Nations produced "a prodigious large belt" given them in 1748 when Johnson entered on the management of their affairs. This had an emblem of the Six Nations joined hand in hand with the English. In 1756 the Six Nations presented a large covenant belt which was expressive of the sentiments of the Five Nations. This phrase was used because the Tuscaroras had not the same dignity as the rest. A speech accompanied the exhibition of this belt, which was not delivered to Johnson but was to be sent "to the Senecas, that from thence it may be conveyed

to the remotest nations as an emblem of the happiness we enjoy by our union, at the same time kindly inviting them to come in and join our Covenant Chain." A description of the belt was added. "This Belt was the largest ever given. Upon it was wrought the sun by way of the emblem of Light, and some figures representing the Six Nations. It was intended to signify that they now saw objects in their proper Light, and that they were fully convinced of the truth of every thing proposed."—*O'Callaghan. Colonial hist.* 7:66. At a council at Fort Johnson the following year this belt appeared again. 'The Senecas spread a prodigious large Belt upon the floor of 30 rows broad of Wampum, with a figure of the sun in the middle and the Six Nations at one end. They told Sir William this belt they had made use of to invite some nations of Indians to remove nearer to them and join their Confederacy. That they had sent to all the scattered Indians of the Six Nations to return and live in their own country. That they had sent messages to their several Allies to dispatch Deputies to a Grand Council they proposed speedily to be held at Onondaga, to take their general welfare under serious consideration. That a great quantity of Belts were already arrived at Onondaga," and they thought the council would assemble in July.—*O'Callaghan. Colonial hist.* 7:265

After Sir William Johnson's death in 1774 this belt was produced by the Six Nations at Guy Park. The Onondaga speaker said: "This is the great Belt of union delivered to us before the late war, for the purpose of peace and friendship with the English. . . This great Belt has always lain at our Council fire, but we shall now deposit it with the Senecas, who are the western door of our confederacy, and whom we thereby charge and injoin to look towards us and to follow strictly the resolutions they have now confirmed with us, and to unite strongly therein.—Delivered an extraordinary Belt, near 5 feet long and consisting of 30 Rows of white wampum in breadth, with a figure of Black wampum in it." As will be seen the leading idea of this belt of union was to bring the Indians themselves into greater harmony.

At a council at Johnstown in the autumn of 1774, the Onondaga

speaker, *Teyawarunte*, produced "the great old *covenant* Chain" of 21 rows, saying: "Brother. This is the Covenant Chain delivered to the whole Six Nations by our late Superintendant in presence of Commissioners from nine Governments, which we have kept clean from rust, and held fast in our hands." This was the conference of seven colonies at Albany in 1754, when Lieut.-Gov. De Lancey delivered this belt to the Six Nations on their behalf, Johnson being present. The chain belt was then explained in the following manner by De Lancey: "This represents the King our common Father —this line represents his arms extended, embracing all us the English and all the Six Nations—These represents the Colonies which are here present and those who desire to be thought present—These represents the Six Nations, and there is a space left to draw in the other Indians—And there in the middle is the line represented which draws us all in under the King our common Father." Virginia and Carolina desired to be considered present. At a council at Fort Johnson in 1756 the speaker held this up, saying: "HERE is the Covenant Chain Belt given to us by eight different governments in the year 1754. We shall on our side keep our eyes upon it and take care that no rust shall injure it, and it shall never be broken on our side." An earlier chain belt was given by Gov. Clinton in 1746, along with war belts and belts of friendship. In the conference of 1755 the chain belt was called the union belt. Johnson gave another and different chain belt at the treaty of Fort Stanwix in 1768. It was briefly described as "Belt of the Cov^{t} Chain 15 Rows with human figures at each end." A conference with the Six Nations and some of their allies in 1759 made another great belt necessary. After suitable words, Johnson "gave over the Cov^{t} Chain Belt, which was a very large black belt, with the figures on it representing 10 Nations of Ind^{s} & the English."

John Long in his *Travels* alludes to another of the great Indian agent's belts. "The wampum belts given to Sir William Johnson of immortal Indian memory, were in several rows, black on each side and white in the middle. The white being placed in the center was to express peace, and that the path between them was open and free. In the center of the belt was a figure of a diamond made of white wampum, which the Indians call the council fire."

Similar belts were much used in Pennsylvania at this time. In the *Memorials of the Moravian church* it is said that on the occasion of a treaty at Philadelphia in 1757, about 12,000 new wampum beads were brought there, " upon which the Indian women were employed to make a belt of a fathom long and 16 beads wide, in the center of which was to be the figure of a man, meaning the governor of Pennsylvania, and five figures to his right and five to his left, meaning the 10 nations mentioned by *Teedyuscung*." That chief sent several belts to the Indians the next year. A large one had five strings or lines across it of white wampum. A white belt had black strings across and was otherwise set with black beads. Another of white wampum had black beads set across. These seem the earliest of these transverse lines, unless the antiquity of the Penn belt is allowed. This figure soon became common. At a council in Easton (Pa.) in 1761, there were many belts with stripes, bars and diamonds, and the width of each belt is given. Some stripes and bars were sloping. At a council in Philadelphia in 1758, a Seneca chief gave " a Belt, on one side of which are three figures of Men in Black Wampum, representing the Shawnees, Delawares, and Mingos, living on the Ohio. On the other Side Four figures representing the United Councils of the Six Nations in their own Country." At Easton, that year, Gov. Denny gave a large belt with a man at each end, and a string of black showing the road from Ohio to Philadelphia. In 1760 a belt of nine rows and two feet long, showed a road passing through 12 towns. Diamonds did not always represent villages or nations. In 1762 a belt of seven rows had two diamonds to show the councilors and warriors united in council. At Lancaster, that year, the Six Nations gave " a Belt of nine Rows, representing the figures of two Men in the middle, with a Heart between them, & Six Diamonds on each side; one of the men represents the Indians, the other the English."—*Penn. Minutes*, 8:747

A few belts of this kind came from Canada. At a council in 1756, the Onondaga speaker described some French belts received in his town, speaking in his proper place. " Then the said speaker moved his seat and placed himself among the Oneida Chiefs and

produced a White Belt wherein a Chain of Friendship was wrought, the Belt was about a Fathom in length, and a Man worked upon it at each end, signifying the Governor of Canada and the Five Nations, holding each other by the hand in token of Friendship, which Belt the commander of the Party, which destroyed Mr Bull's Fort and party at the great carrying place, gave to an Oneida Indian who was hunting, some distance from said Fort just before it was destroyed."—*O'Callaghan. Colonial hist.* 7:137. The next year the French sent a very long black war belt of 6000 beads to the Six Nations, with an axe worked in the middle. Such belts were frequent, and a similar one with two hatchets was sent by the French at a later day. Among the belts given at a council at Montreal in 1754, one represented "the two villages of the Oneidas, Cayugas and *Kaskarorens*." Two paths on it terminated at a friendly place.

Among later belts may be mentioned one shown by the Shawnees to the Iroquois in 1771, representing them and the Illinois, with 10 confederated tribes between. Besides the great one, other chain belts appear. In 1773 the Six Nations presented a covenant chain belt to Johnson of 11 rows and 12 squares. He returned a black one of 13 rows with white squares. After his death the Oneidas showed a large white belt with black diamonds, which he had given them. Belts of this description have been preserved.

A few post-colonial belts may be mentioned. At a council at the Onondaga village near Buffalo in 1793, a western belt presented was of white wampum "made in a circular form, representing their place of meeting as in the center, and crossed by four stripes of black wampum, representing all their confederates, east, west, north and south." At the same time "the Wyandots spoke with a very large belt with three pictures on it—the Americans at one end, the Six Nations in the middle, and themselves at the other end." While waiting near Detroit for a share in the council at Miami rapids the same year, the United States commissioners gave the Wyandots a white belt with 13 stripes of black wampum.

The rupture between England and the colonies brought out some belts at conferences with the Iroquois. The Oneidas came to Col. Johnson for advice on political troubles and showed a black belt of

nine rows. On this were white letters and figures, W: I. and 1756. The Six Nations afterward met the colonial commissioners at German Flats. This was preliminary to a more important council at Albany in August 1775. As a symbol of the troubled times a broken belt was one of those presented by the commissioners. A new union belt was given by them. It represented the 12 united colonies, and was followed on their part by "the large belt of intelligence and declaration." Then followed the path belt, and the pipe of peace with six small strings. The Indians there referred to an old covenant belt of 20 rows between the Oneidas and Peter Schuyler, and another given by the Senecas. These old belts were again brought out at Albany.

In these many accounts of belts of this kind the development of emblems and the probable date of each may be seen. Many were arbitrary, and the exact meaning could only be known by tradition, which often proves a misleading guide with existing belts. Others had their meaning explained when given, to the great relief of those who received them. While a line may mean a road, a square or diamond a castle or nation, clasped hands alliances and hatchets war, it does not always clearly appear what road, nation, alliance or war is intended. The interpretation depends on the occasion, and the true meaning may be forgotten. In Pierre Margry's *Découvertes et établissements des Francais*, pt 5, p. 290-91, is a conversation between Capt. de Lamothe Cadillac and the Huron chief Quarante-Sols. It was at a council at Fort Pontchartrain, June 3, 1703.

Quarante-Sols. I came on my way to tell you what I propose to do at Montreal. Here is a collar which has been sent to us by the Iroquois, and which the Ottawas have brought us; we do not know what it signifies.

M. de Lamothe. How have you received this collar without knowing the purpose for which it was sent you?

Quarante-Sols. It has already been long since we received it. I was not there, and our old men have forgotten what it said.

M. de Lamothe. Your old men are not regarded as children to have such a short memory.

Quarante-Sols. We do not accept this collar; but we are going to take it to Sonnontouan to find out what it means, because it is a serious matter not to respond to a collar; it is the custom among

us. The Ottawas can tell you what it is, because our people have forgotten it.

M. de Lamothe. The Ottawas will reply that, having received it, you should remember it, but since this collar is dumb and has lost its speech, I am obliged to be silent myself.

Pontiac's great wampum belt is said to have been 6 feet long and 4 inches wide, and would thus have contained 9000 beads. It was covered with emblems of the 47 tribes and villages in alliance with him.

In the *History of the Ojebway Indians*, by the Rev. Peter Jones, p. 121, is an interesting description of a modern belt.

Firstly, the council fire at the Sault Ste Marie has no emblem, because there the council was held. Secondly, the council fire at Manitoulin has the emblem of a beautiful white fish; this signifies purity, or a clean, white heart—that all our hearts ought to be white toward each other. Thirdly, the emblem of a beaver, placed on an island on Penetanguishew bay, denotes wisdom—that all the acts of our fathers were done in wisdom. Fourthly, the emblem of a white deer, placed at Lake Simcoe, signified superiority; the dish and ladles at the same place indicated abundance of game and food. Fifthly, the eagle perched on a tall pinetree at the Credit denotes watching, and swiftness in carrying messages. The eagle was to watch all the council fires between the Six Nations and the Ojebways, and being farsighted, he might, in the event of anything happening, communicate the tidings to the distant tribes. Sixthly, the sun was hung up in the center of the belt to show that their acts were done in the face of the sun, by whom they swore that they would forever after observe the treaties made between the two parties.

This highly artificial character may be contrasted with the simplicity of early belts.

In a meeting between Johnson and some Cherokees in 1758, it is said: "The Cherokee spoke to the Belt of Wampum, addressing himself to Sir Wm., and the Belt of Wamp spoke it out in his own language." The Cherokees "gave a white belt, with one black row of wampum in it signifying the road, & 3 figures of men signifying Sir Wm. Johnson, & the Kophy & Tsyody nations."—*O'Callaghan. Colonial hist.* 2:766. In this case the Belt of Wampum who speaks is the Seneca chief known by this name, and also as Old Belt.

In David Boyle's *Fourth annual report of the Canadian institute,*

p. 23, there is a figure of porcupine quill work very suggestive of the wampum belt, having a similar plan, with the several divisions about the size of the beads used in the belts. 21 rows of the pattern, with the outer bands, have a depth of 5 inches, while the equivalents of 55 beads, measured the other way, are placed beside each other for a space of 4.875 inches. This gives nearly 11 to the inch, which is somewhat narrower than the average beads used in belts, but about the usual length. Mr Boyle says that 55 narrow strips of leather were used as a warp, the ends being neatly bound. His account of the weaving of the belt would require double this number. When thus bound at the ends, "the strips were then bound two and two by means of porcupine quills wound four or five times round, and fastened so ingeniously that even with a magnifying glass it is difficult to perceive how the work has been done. One row (say the top row in the plate) having been so formed, the next was commenced by binding the outer strip singly and thereafter taking one from each adjoining group of two above. In forming the third row the same strips would be bound as in the first row; and in the fourth as in the second, and so on. Meanwhile the pattern must have been clearly defined in the mind of the artist, for this is really a bit of artistic work, the purely ornamental portion of which speaks for itself both in color and design. The central figure demands a little more attention. At first sight one would hardly recognize it as a bird—perhaps not even at second or third sight, but there can hardly be a doubt that it is meant to represent the eagle or great thunder-bird, the belief in which is or was widely spread among the Indians over the northern part of this continent. The only claim that can be made for this conception of the thunder-bird is that as nearly as possible it is symmetrical—the method of working led to that."

The pattern has the long points or serrations found on recent wampum belts. These are in white, blue and light brown. The ground is red, and the bird is black edged with white. The binding of the leather strips in this alternate way makes the fabric very strong and has a pleasing effect on the pattern.

In *Eastern Maine and Nova Scotia in the revolution*, p. 286, Mr

Kidder speaks of a belt presented by the Indians of Maine as a pledge of friendship to the United States and France. A cross signified the latter, the 13 rows of the belt the former, and the Indian villages were shown by several white figures.

Underground. Underground belts are sometimes mentioned. Heckewelder says, page 109: "If the message be of a private nature, they are charged to draw or take it *underground,* that is, not to make it known to any person whatsoever, except to him to whom it is directed. If they are told to enter *into the earth* with the message or speech, and rise again at the place where they are to deliver it, it is to desire them to be careful not to be seen by the way by any person, and for that purpose to avoid all paths, and travel through the woods." In 1694 the Iroquois sent an underground belt to those of the Sault in Canada, with this message: "I put this message between you two underground, where it is to remain three years, in order to say to you that you must think much of the union that ought to exist between us, and not forget that here is your ancient country; that you ought to advise us of the designs of *Onontio* without letting him know it. Fear not visiting us; you will be always welcome." Father Lamberville handled many such belts at Onondaga. In August 1684 he wrote to De la Barre: "I gave La Grande Gueule your belt under hand, and remarked to him the things which you wish him to effect." This was *Hotreouaté,* better known to us as *Garangula,* who was the orator shown in the plan of De la Barre's camp.

Disposition. Colden said (p. 109) that the belts and other presents received from the western Indians at the council at Onondaga in 1690, were hung up in the council house and afterward distributed. One large belt was sent to Albany, and another from Albany was hung up and afterward divided. Lafitau said the nobles "furnish them, and it is among them that they are redivided when presents are made to the village, and when replies to the belts of their ambassadors are sent. . . Their wampum would soon be exhausted if it did not circulate; but in almost all affairs, either within or without, the law requires a reply, word for word, that is to say, for one belt one must give another, to be of about

the same value, observing however a slight difference in the number of beads, which must be proportioned to the rank of the persons or nations with which they treat." The note to Montcalm's letter is in the same words. La Hontan said: "Sometimes they keep for an age the collars that they have received from their neighbors, and, in consideration that every collar has its peculiar mark, they learn from the old persons the circumstances of the time and place in which they were delivered; but after that age is over they are made use of for new treaties." If they were but formal presents, they were often taken to pieces and distributed at once. This shows how little reason there is to think any belt left in Indian hands is of any great age, even were nothing else alleged.

Recent. Among the belts procured for the state museum by Mrs Harriet Maxwell Converse is one formerly held by Gen. Ely S. Parker, and represented in fig. 231. Her notes on this are given in full and some are attached to the belts.

Five council fires, or death belt of the Five Iroquois Nations, or the confederacy of the Iroquois. This belt I value perhaps more than any other in the possession of the state, inasmuch as the death belts were in the custody of the keepers of the east and west doors of the *Ho-de-ne-sau-neh*. This one was always held by the *Do-ne-ho-ga-wah*, the keeper of the west door, the Seneca nation, who were the guardian of the west door, the watcher and army guard of the confederacy. The Mohawks of the east door should have its mate in Canada. This belt signified death or war against some other nation or nations. When it was sent to the east door, the Hudson river, it was held in the council of war of each of the nations, Cayugas, Oneidas, Onondagas, Senecas and Mohawks, till returned by the latter, which signal was that the war must begin at once. It represented death or *absolute* extermination, or *absorption* by adding to the numbers of the Iroquois, whichever they decided on. The red paint, with which it was always decorated at the time of its journeys may be seen on it now.

In 1845 the Senecas abandoned the tribal government, and the one surviving portion of the body—the Tonawanda Senecas, became the actual proprietors of the death belt. During the lifetime of the *Donehogawah*, Gen. Ely S. Parker, he held it, and bequeathed it to his daughter. By the consent of his widow I have procured it for the state. To the Tonawandas it was of no material value, as they have been at peace for more than a century; therefore they relinquished their title to it when they ratified the transfer of the

wampum to the University of the State of New York last June. This precious relic will now forever remain with the state, and it is my request that the name of Gen. Ely S. Parker shall be attached to it in his memory, not only as the most distinguished of his later people, but as the last "keeper of the west door" of the confederacy of the Iroquois. At the condolence council of Gen. Parker another *Donehogawah* sachem—one of the 52 names that were hereditary in the nation—was raised or appointed as the successor of Gen. Parker, but the remnant of the Senecas is so feeble that the present sachem would not by law hold the belt. Some day the state of New York may get its brother belt of the Mohawks. I hope for it.

The statement given by the Senecas shows the small value to be attached to Indian traditions; and their ideas of this fine belt seem to have completely changed in the century and more in which it may have been held by them. Mrs Converse has wisely called attention to the red paint still to be seen on some of the beads, and which changed any belt into one of war. War belts may be reckoned by scores. This belt is a recent one of purple wampum, having the Five Nations represented by five open hexagons of white beads. Three rows of five white beads at each end alternate with the purple. A belt recently held by the Onondagas is almost the exact counterpart of this. In both, the hexagons represent the nations and they could be transformed into war belts by the use of red paint. The general design was common. Used as a war belt it might have been sent to or by the Five Nations. In the latter case the proposal of war was rejected, and the belt was returned. It was customary for any of the Five Nations to propose war by a belt, or even to carry it on alone, but a general war could be determined only by the grand council at Onondaga. War belts might call this council together, but they only proposed war. This belt is 38 inches long in the beaded part, or 370 beads. The full width is 2 inches, or seven rows. The buckskin thongs are about 3.5 inches long at the ends, the outer ones being double and twisted.

L. H. Morgan gives a list of 50 Iroquois principal chiefs, eight of whom were Senecas, the last being *Do-ne-ho-gá-weh*, or Open door. He says: "The Senecas were made the doorkeepers of the Long House, and having imposed upon *Do-ne-ho-gá-weh*, the eighth sachem, the duty of watching the door, they gave to him a sub-

sachem." The Senecas were called *Ho-nan-ne-hó-ont*, the door-keeper. Horatio Hale gives a list of 52 principal chiefs, the last of the eight Senecas being *Teyoninhokawarenh* in Mohawk. The Onondagas call him *Ta-ho-ne-ho-gah-wen*. In every form it means the same. In the condolence song, however, it is said of him and another, "these two guarded the doorway," and their business was to transmit messages from without, not to originate them. The national or federal council did that.

Fig. 230 is called a condolence belt, at first with the name of Red Jacket, but Mrs Converse afterward found it was a Cornplanter belt. It is of purple beads, seven rows deep, but has lost some beads from the central part. The beaded portion is about 328 beads, or 36.25 inches long, being defective at one end. The full width is not 2 inches. The outside thongs are of double and twisted buckskin; the inner, narrow and single. The five equidistant vacant spaces may have had white diamonds. This was a private belt, not related to those of the confederacy, and not in the wampum keeper's care. Fig. 32*a* represents part of another belonging to Rev. W. M. Beauchamp, and obtained from an Indian woman. It is of nine rows, having three white rows on each side and one in the middle. A dark row of thinner beads is on each side of the last. It has been cut off at both ends, but the rows are now 65 beads long, with a full width of 3 inches. The beads are strung with a double thread of hemp on single buckskin thongs. The lines would indicate part of an alliance belt.

Fig. 243 is of a mutilated belt, nearly 2 inches wide and now 16.63 inches long. It is seven beads deep and 135 long, made on fine buckskin thongs, the outer ones double and the inner single. Three open white diamonds appear on a purple ground. These represent nations, and two more would make it a Five Nations belt, with a length of about 2 feet. The writer afterward saw and figured the remainder of this belt, and found his conjectures verified. The piece cut off is 59 beads long, has the two diamonds, and makes the complete belt exactly 2 feet long. It is a good specimen of this class, and the division took place for the convenience of a friend of the writer. Mrs Converse's note follows:

Ransom belt of wampum. This belt has been divided according to the old law. If a sachem or chief was captured and condemned to die, or a murder committed, a certain amount of wampum would ransom him. In this instance the captive must have been of prominence or of national importance, as the entire belt has been divided. How much of it is missing I can not determine positively, but, as the usual length of a wampum belt is about 3 feet, I conclude that about one half has been taken. The diagonals of white wampum signify the tribal fires or the eight clans of the Senecas—Wolf, Bear, Beaver, Turtle, Deer, Heron, Hawk and Snipe. This belt is exceptionally rare and has no duplicate. I obtained it from a direct descendant of Mary Jamieson—the celebrated white woman captive—in whose care it had been placed by the Senecas. She guarded it till her death, when it reverted to her heirs, by whom it has been held till now—the fourth generation. It is one of the national belts of the Senecas.—" *Harriet Maxwell Converse, Cattaraugus reservation,* 23 June 1899 "

As above noted, the writer saw the rest of the belt a few weeks later. It presents no unusual features, and the five diamonds represent the Five Nations, the Tuscaroras being commonly omitted. Atonement was often made with strung wampum or other presents, which were given to the person or family injured, not to the nation as a rule. Atonement or ransom might be refused. When belts were given to the nation, they seem to have been for the family, were reckoned at their money value, and were soon used as money. In this case Indian tradition seems to have widely departed from the original meaning.

Fig. 245 is another fragment of a purple belt without figures, which is a little over 7 inches long by 2.75 wide. The depth is 10 beads, and it is 77 beads long. Mrs Converse calls it the Cornplanter wampum belt, and says:

This is a portion of the treaty, and should be kept with it always. The belt has been mutilated by dividing it among Cornplanter's heirs at the time of his death. It is impossible to obtain any of the divided portions, the beads having been separated and arranged in strings for burials or councils. This remnant has never been separated from the treaty, and is a record of the history of the Five Nations. Cornplanter's name and mark head the list of the chiefs who signed, and the treaty and belt were given to him to preserve for his people.—" *H. M. Converse. At the Cornplanter reservation,* June 1899 "

This reservation was patented to Cornplanter by Pennsylvania in 1796. His Indian name is variously given in treaties and deeds, but is *Gy-ant-wa-hia* on his monument. He was long a noted Seneca chief and died at an advanced age in 1836. Mrs. Converse visited this and other reservations, and secured many of the belts in the state collection.

Three belts are represented which are in the national museum at Washington. Fig. 268 shows the largest, which has white figures on a dark ground. It is of 14 rows, the extreme width being 4 inches, and was obtained of W. N. Thompson, Chatham, Can. The beaded part is 41 inches long, or 238 beads. These are mostly dark and rather variable in thickness. One white bead in the outside row is $\frac{5}{8}$ of an inch long, but most are less than a quarter of an inch. The thongs are of plain buckskin. It is said to have belonged to Tecumseh, and this seems not improbable. On the other hand Andrew John, a Cattaraugus Seneca, made this note on it, which is preserved at Washington:

Wampum belt of the Iroquois Indians. This shows the formation of the confederacy called the Five Nations. The five figures of men represent the five tribes of this people as united to form a government of the league. The right hand wigwams are supposed to be the western end of their territory, and the first man to the right represents the Seneca, the doorkeeper to the league, the second the Cayuga tribe, the third the Oneida, the fourth the Mohawk, and the fifth the Onondaga. The first house is the council house, the next five are the original wigwams of the Five Nations, the seventh or last house is the one added to the confederacy, or the Tuscarora tribe, now known as the Iroquois confederacy. —*Andrew John*

This is rather fanciful, and the Iroquois are fond of referring all they can to the foundation of the league. There are actually eight houses on the belt, which may be read in reverse order, being alike on both sides. Two houses are broader than those at the other end of the belt, made in a different way and without pinnacles. They are not united. Three figures of men next these stand apart and are nations not in alliance as yet, though this may be sought. Two joining hands and supporting a flag between them are in active alliance, and may be the British and Shawnees. Six cabins

united by a basal line may be the Six Nations, whose alliance is sought. They are distinguished from those at the other end by side pinnacles, which may be chimneys, indicating their advanced condition. This is partly conjectural, but would agree with the supposed history of the belt.

Fig. 269 represents a belt ascribed to the same period, but probably not made by Indians. It came from Willis N. Tobias of Moraviantown, Canada, and is a white belt of 244 beads, or 37 inches in length. In the figure it has been folded more than the last, and has a width of 11 rows or 2.75 inches. The large white and purple beads have a foundation of coarse red twine. The two human figures, clasping hands, show an alliance, but are not in the usual conventional Indian form, while the letters, I. G. S., point to a European source. The former owner wrote to the national museum: "The belt is a good one and relates to the schemes of the renowned Shawnee chief, Tecumseh. This is a companion belt to the one you purchased from Mr Thompson, and is supposed (there is no documentary evidence) to be the record of a peace treaty in which the hatchet is buried and the hands joined in friendship between the tribes, who unite in war against the wigwams of the white man. It is certain that these are records of the offensive and defensive alliances formed by Tecumseh against the hated Long Knives, or Americans." The letters, however, make it evident that the alliance in one belt was between the Indians and civilized men. These would refer to some prominent officer, and the writer identifies them with the initials of John Graves Simcoe, governor-general of Upper Canada, 1791-94.

Fig. 270 shows a small belt whose history is now unknown, but which is supposed to have belonged to the Mohawks. The beaded part is 20 inches, or 160 beads long and is six rows deep. The beads are quite uneven, but have the usual average length. Purple beads form the ground, and on this are two very broad open diamonds in white beads. Three short rows of white alternate with the purple at one end, and at the other are six rows of white alternately long and short. The thongs are of twisted buckskin. These were kindly photographed at the national museum to illustrate this bulletin, a favor gratefully acknowledged.

The first definite account we have of the later Iroquois belts in the custody of the Onondagas is that given by J. V. H. Clark in his history, in 1849, 1:124-25. The belts had been kept on the Buffalo reservation till 1847 by *Ut-ha-wa*, or Capt. Cold, an Onondaga chief. In that year the council fire was restored to Onondaga, and Mr Clark's account follows.

Dehatkatons was at that time chosen keeper of the council fire of the Six Nations. These archives consist of various belts of wampum, some 25 or 30 in number, which the author has had the satisfaction of seeing, (a sight rarely allowed a white man) with explanations from the keeper. Here is shown a belt, 16 inches broad by 4 feet long, representing the first union and league of the Five Nations, and is called the *carpet*, foundation or platform, or as we may better understand it, the constitution; literally something to stand upon. The several nations are distinguished by particular squares, and these are joined together by a line of white wampum and united to a heart in the center, implying the union of heart and hand as one. In connection with this is a second belt having the figures of several chiefs wrought in the wampum, all holding hands in a circle, which is to represent that there shall be no end to the league.

On one belt is figured the Long House, the Great Cabin, which no new nation can enter till it has erected some little cabins around it; that is, the nation must perform some deeds worthy of note before it can be entitled to admission to the great league of confederation. Around this are five smaller cabins, emblems of the original Five Nations before the league was formed, and on one side is a still smaller one, wrought since the first, representing the Tuscarora nation, which was admitted at a subsequent period. Another long narrow belt, having a cross at one end and a Long House at the other, a narrow white stripe connecting the Long House and a large cross, was explained as follows: "Great many years ago" a company from Canada presented this belt, desiring that missionaries from the Roman catholic church might be settled among the Five Nations and erect a church at Onondaga, and that the road should be continually kept open and free between them. All the other belts were explained with particular minuteness.

The bag which contains these relics is of itself a singular curiosity. It is made of the finest shreds of elm bark, and a person without being apprised might easily mistake it for the softest flax. Its capacity would exceed a bushel. The bag is reputed to be as old as the league itself, and certainly bears the marks of great antiquity. The tubes or beads of wampum are of red, dark blue, pale blue, black and white colors, made of conch shell. They are about $\frac{5}{8}$

of an inch long, about as large as a small pipestem and hollow, strung, woven and wrought with sinews of deer, and bark.

Mr Clark's dimensions of beads and belts are too large, but his account may be compared with those more definite and later. The rapid decrease in the number of belts may also be noted. They were not seen again by a white man till the summer of 1878, when the writer examined them at Thomas Webster's house. That fall Gen. J. S. Clark obtained small photographs under difficulties, and from these were made large drawings to illustrate W. H. Holmes's excellent paper on the shell articles of North America. Since that time the writer has had several ample opportunities of examining all these belts, and the widest two were secured by him for the state museum. There were but 12 remaining when he first saw them, and, if Clark is correct, more than half had disappeared within 30 years. Some fine belts were certainly lost.

During his knowledge of them various and conflicting interpretations of these belts have come before the writer. Some will be given to show how little is certainly known. Fig. 252 is the reputed original record of the formation of the league, and the tradition is constant. Clark had this interpretation, but exaggerated the belt's dimensions. Instead of being 4 feet long by 16 inches broad, it was 10.5 inches wide by 23 long in 1878, showing a great loss at each end. The width of course had not suffered. When exhibited in Syracuse in 1886 it was said: "This belt was used at the great council which met to ratify the union of the Five Nations. The age is unknown; nothing but the tradition of the council remains." Gen. Carrington, who obtained this from the Onondagas, calls it "the official memorial of the organization of the Iroquois confederacy, relating back to the middle of the 16th century." It is sometimes called the Hi-a-wat-ha belt, and has been in controversy in our courts over a question of ownership. It is a fine modern belt of 38 rows, made on buckskin thongs, the outer ones braided, and is strung with flax or hemp thread. The beads were made with modern tools and are mostly purple. There is a conventional heart in the center, and four open castles remain in white beads. As the pattern shows that there were others beyond these on either

hand, this plainly proves that it had no reference to the original league. It is probably not 150 years old. There are good pictures of all in the census of 1900. Gen. Carrington was special agent for the census of 1890, and his farther notes will be credited to Thomas Donaldson, the compiler of the report on the Six Nations of New York.

Fig. 244 represents the widest belt known, one of 50 rows wide. Through a slight mistake of the writer this was reported to Mr Holmes as 49 rows. It is 14.75 inches wide and about 35 inches long. Though not of the original length it has not been diminished since it was first pictured. The pattern is decidedly modern as well as the material. It is made on small buckskin thongs with a hard, red thread. The interpretation of 1886 was, " The second belt used by the principal chief of the Six Nations. Very old." Mr T. Donaldson's note is similar. He calls it " Wing or Dust Fan of Presidentia of Six Nations." Also " the wing mat used by the head man to shield him from the dust while presiding at the council." It seems to represent an alliance actual or proposed, and to be of the variety termed chain belts.

Fig. 232 is another modern belt of the same date, termed by Mr Donaldson, " Presidentia of the Iroquois, about 1540." A series of dark points inclose open white diamonds, signifying nations or towns. It is properly a chain belt, showing a completed covenant. When Gen. Carrington photographed it in 1890, it had lost nothing since first seen by the writer. Before it again came into the latter's hands it had been reduced from 16 to 14 diamonds. It is 45 rows wide or 13.5 inches, and was incomplete in length when examined in 1878. The material is as in the last, and both seem to have been made by one person. The note of 1886 says, " The first belt used by the principal chief of the Six Nations. Very old." Both these were secured for the state in 1898, and they are the broadest on record. Unique in every way their modern origin is at once apparent to any careful observer, but no definite date can be given them. One reason for this failure of a true tradition is very clear. The belts were brought to Onondaga in 1847 and placed in La Fort's hands. He died a year later, and, if familiar with them him-

self, had but a brief opportunity to convey his knowledge, if he did this at all. They then came into the hands of the Websters as a matter of convenience, and they had no training for the office. Thomas Webster certainly gave meanings to suit himself or his visitors, not knowing their history.

Fig. 248 is 15 rows or 5 inches wide, is nearly 6 feet long and has purple figures on a white foundation. There are 8½ beads to the inch of length, and it is on twine thongs. All agree that this is a covenant belt with the 13 original United States, but the interpretation of parts varies. Donaldson says it is a "memorial of the first treaty made by Washington on behalf of the 13 original states and the president of the Six Nations at the national capitol." Others have seen in the central house the capitol building at Washington, and in the two men within this representatives of the contracting parties. The writer's opinion has been that the central part of the house contains the Iroquois council fire, with an Indian on either side clasping hands in alliance or friendship with the states outside. This may be one of the belts which Clark thought connected with the formation of the league.

Fig. 237 is the belt which Clark thought was a French missionary belt, and which has long had that reputation. Mr Shea and others have felt very sure that it is a belt given to the Onondagas by Chaumonot in 1655, but this has a very slender foundation. There is no hint that he presented any emblematic belt, and no probability that any French belt would have been kept through the succeeding wars. The Jesuits allude to none so held. The groundwork of purple wampum is almost conclusive against its antiquity. On the other hand a similar belt is on record over a century later. In 1775 the Moravian Indians sent a belt to the grand council of the Delawares, which was 3 feet long, having a white cross at one end and a band through the middle. (*De Schweinitz*, p. 426) As the Moravians and their Indians had frequent business at Onondaga, this belt is more likely to have been Moravian than French, if its character is allowed. The cross, however, was a frequent symbol of Canada, considered as a country. The sole reason for the missionary theory is found in the cross terminating the white line which reaches the

man's head toward the other end. At the feet of this human figure is an open diamond, representing a castle. Donaldson described it as showing "the guarded approach of strangers to the councils of the Five Nations;" by no means a bad interpretation. Probably in this case the cross would be the strangers coming by the path of peace, which is guarded by the warrior or chief before the castle. In 1886 Webster described this as a belt of admission to the league. It is on buckskin thongs, and strung with fine white thread. The width is seven rows or 2.5 inches.

Fig. 238 is another of the Onondaga belts, six rows deep or 2.25 inches wide, and made on twine thongs. A curious feature is that in the squares there are two rows of dark beads to one of white. Carrington's picture gives but four of the sloping lines of black beads. It had five when first seen by the writer, being then perfect and probably relating to the Five Nations. It is noticeable how this loss changed the meaning, which Donaldson gives as "a treaty where but four of the Six Nations were represented." In 1886 Webster said that this and some others "represent the submission of each tribe when they joined the confederacy and were turned over to the wampum keepers.

Fig. 251 had the same meaning given to it by Webster, and the fondness for a similar interpretation is noticeable. It is a fine belt of seven rows, with open white hexagons on a purple ground, being almost the counterpart of the Parker belt. It has buckskin thongs and black thread. Donaldson speaks of this as a belt "claiming to bear date about 1608, when Champlain joined the Algonquins against the Iroquois." It is by no means so old, and has been mutilated since it was first seen by the writer. It was then perfect.

Fig. 240 is a belt of 12 rows with black diagonal bars on a white foundation, and it is imperfect at both ends. It had seven full bars when first seen by the writer, but Mr Carrington's picture shows but six and perhaps part of another. According to him it "represents a convention of the Six Nations at the adoption of the Tuscaroras into the league." This is not satisfactory, but no other meaning has been given. It is on buckskin thongs. Sloping lines are said to be temporary alliances.

Fig. 239 is of seven rows, and has four pairs of black diamonds on a white ground. The diamonds are linked in pairs. Among the black beads at one end is a small white cross. Donaldson says of this that, having "the Five Nations upon seven strands, it illustrates a treaty with seven Canadian tribes before the year 1600." It is probable there should be another pair of diamonds, but this age can hardly be allowed, as these tribes came into existence in the 18th century. Wampum like this was not known in the interior of New York till very much later than his date. In 1886 Webster called it a belt of admission to the league. It is a recent belt on buckskin thongs.

Fig. 249 was once a fine belt of 13 rows, but is now quite defective, having lost much since first seen by the writer. The ground is of white beads, with four triple diagonal lines of black. The outer lines of these are two beads deep, the inner one being separated by white lines of two beads. This is on buckskin thongs.

Fig. 236 is a belt of 7 rows, with a zigzag pattern at one end and a series of small dark crosses. Donaldson says this "embodies the pledge of seven Canadian Christianized nations to abandon their crooked ways and keep an honest peace." The interpretation of 1886 was "St Regis tribe belt, given to mark their submission to the power of the Six Nations, with a promise of peace." The St Regis Indians are mostly of Iroquois stock, and about 150 years old as a people. This belt has twine thongs, and may have been made by white men. Fig. 250 shows what remained of another belt in 1878. It was probably a belt of eight rows. These were all then remaining out of double the number shown to Mr Clark 30 years earlier. The missing ones had been consumed in messages, offerings and ceremonies.

H. E. Krehbiel published some articles in the *New York tribune*, July 1897, on the Canadian Iroquois belts shown him by John Buck, or *Skan-a-wah-ti*, in 1892. Nation for nation, and chief for chief, the Six Nations of Canada keep up the same organization as in New York, and Buck was then wampum keeper. Mr Krehbiel said:

On one of them was a row of figures like half diamonds, each extending across the belt. From Buck's explanation I gathered that the figures were conventionalized hearts. This perpetuated the memory of a treaty. "With what tribe?" I asked. "The Eries," answered Buck. "About what time?" "About 200 years after the white man came to America." This illustrates the starting point which Buck chose for nearly all his estimates of time. So many years or centuries before or after the white man came.

Belts of pure white beads Buck described as records of treaties of peace. Stripes diagonally across a belt, he said, were symbols of agreement that the tribe giving it would help the Six Nations in war—the diagonal figure being intended as props for the Long House, the symbol of the confederacy. One belt which showed in its middle an oblong figure with a spot in its center, Buck said was the record of a treaty granting hunting and fishing privileges, that is to say, the tribes exchanging the belts agreed to use certain hunting and fishing territory in common. When asked how this was symbolized by the design on the belt, Buck explained that the parallelogram was a dish, the spot in its center a piece of meat. A belt of purple containing a white conventionalized design like that commonly called the Greek key pattern (a meander) was said to have been sent by whites as a confirmation of a treaty.

The collection of belts brought by Buck did not appear so numerous as that shown (1871) on Mr Hale's photograph. Its most interesting feature was half of the belt which, according to tradition, signalized the formation of the Iroquois confederacy. The circumstance that he had only half the belt Buck explained by saying that, when the Six Nations separated after the American revolution, the majority leaving their ancestral home in what is now New York state to become the wards of the British people, for whom they had fought, in Canada, the wampum belts were divided between the two bodies. In the case of this belt, the league belt, neither body wished to surrender it to the other, so it was cut in two and each body took a half. This belt, however, is not that which is described as the Hiawatha belt, in the possession of the mayor of Albany.

The latter belt, according to a description recently printed, contains four oblong figures, 4 inches by 5, two of which are on either side of a diamond-shaped figure in the middle. All the figures are connected by links and are expounded as follows: The diamond represents the Onondaga nation, which was the wealthiest and most powerful. The other four figures stand for the Senecas, Mohawks, Cayugas and Oneidas. These were the original five nations of the confederacy. Now the half believed by the Canadian Iroquois to be the record of the formation of the league, (the Great Peace, as Mr Hale would have called it) shows only a row of conventionalized human figures clasping hands, an exceedingly rude and simple

design, for all the world like the chains of dolls which are cut out of paper to amuse children.

Mr Krehbiel referred to a photograph procured by Horatio Hale in September 1871, when he gathered six Iroquois chiefs on the Canadian reservation near Brantford. "There all the wampum belts were brought and their meaning was explained to Mr Hale. A photograph of the group preserves the incident." The chiefs present were all well known, but many years later the picture and chiefs did duty in an unexpected way. If the reader is curious in the matter, he will find all, including the names, in the United States census of the Six Nations of New York for 1890, under the title, "Reading the wampum, 1890," and with this note, "The reading of the wampums to the representatives of the tribes gathered at St Regis makes a suggestive picture." Then follow the names of the chiefs given by Mr Hale many years before. In the picture over a dozen belts appear. On the back of the photograph here used, from which the illustration mentioned was taken, Mr Hale wrote:

This picture represents the chiefs of the Six Nations, on their reserve near Brantford in Canada, explaining their wampum belts. (Sep. 14, 1871) These chiefs were

1 Joseph Snow (*Hahriron*) Onondaga chief

2 George H. M. Johnson (*Deyonhehgon*) Mohawk chief and government interpreter. Son of no 4

3 John Buck (*Skanawatih*) Onondaga chief and wampum keeper

4 John Smoke Johnson (*Sakayenkwaraton*) Mohawk chief and speaker of the council

5 Isaac Hill (*Kawenenseronton*) Onondaga chief and fire keeper

6 Seneca Johnson (*Kanonkeredawih*) Seneca chief

The wampum belts were explained to me on the reserve, at the residence of Chief G. H. M. Johnson; and at my request the chiefs afterwards came with me to Brantford, where the original photograph (of which this is a copy) was taken.—*H. Hale. Clinton Ont.*

Quite a difference will be noticed between the Indian names here and in the census report, while the English names are the same. Frequent correspondence with Mr Hale enables the writer to say that the above is an absolutely true copy. The numbers are to be read from left to right in fig. 281. One face has been turned.

An officer is mentioned among these Canadian chiefs who does not appear on New York reservations. The Canadian Iroquois have fire keepers, representing the Onondagas, and their office is peculiar. It may partially appear in the writer's visit to the Six Nations' council at *Ohsweken*, Canada, September 1899, asking permission to photograph their few remaining belts. Chief J. S. Johnson introduced him to the secretary, and he was escorted to the highest seat, and placed with the two interpreters. This was at the end of the large council room and facing the audience. On the platform before him sat the secretary, a step lower down, with the speaker on his right. On still lower seats against the two side walls were the chiefs of the two brotherhoods, and in front of the speaker and facing him were the Onondaga fire keepers. The petitioner was introduced, rose and made his request, which was translated by an interpreter as usual. The chiefs of two of the Elder Brothers, the Mohawks and Senecas, quietly consulted, and then a Mohawk chief gave a favorable opinion to those opposite. The Younger Brothers, the Oneidas, Cayugas and Tuscaroras, did the same, and an Oneida chief announced their concurrence. Had they not agreed, the fire keepers would have had the decision. As it was, they merely made a favorable report. Then the speaker announced the full opinion, which was interpreted to the visitor in a dignified and lengthy speech, and to which he made a suitable response. It seems quite a long process, but, as there was no public debate or voting, it really took no more time than many such things with us. No wampum strings were used; for they had none left, and this mode of holding a council is a modern innovation.

Pres. Washington gave a white belt to the Six Nations in 1792, with these words, "As an evidence of the sincerity of the desire of the United States for perfect peace and friendship with you, I deliver you this white belt of wampum, which I request you will safely keep." In his speech, July 28, 1812, Red Jacket said that Washington had once presented a chain belt. "Upon this belt of wampum he placed a silver seal. This belt we always have and always wish to look upon as sacred." Red Jacket had this belt identified by white men present. An eagle was engraved on the

seal as an emblem of the United States, but the belt seems different from that mentioned above, as it was called a curious one. The chief did not stop with this. "He likewise held up another belt, much larger, of different colors, which appeared to be very ancient. . . . 'Brother, I will now state to you the meaning of this belt. A long time ago the Six Nations had formed an union. They had no means of writing their treaties on paper and of preserving them in the manner the white people do. We therefore made this belt, which shows that the Six Nations have bound themselves firmly together; that it is their determination to remain united, that they will never do any thing contrary to the interests of the whole, but that they will always act towards each other like brothers."—*Stone*, p. 230-32. No description of this belt appears, but the Onondaga belts were then kept at Buffalo. It may be added that it was not customary to place the Tuscaroras on the Iroquois belts, as they were not considered a part of the Long House.

It may be of interest to repeat what some Onondagas have said of their belts. In 1888 Thomas Webster, the wampum keeper, declared that the wampum "means nothing to the white man; all to the Indian. There is a tree set in the ground and it touches the heavens. Under that tree sits this wampum. It sets on a log. Coals of fire is unquenchable, and the Six Nations are at this council fire held by this tribe. *To-do-da-ho*, a member of the Bear clan, is the great chief here. . . . One of the uses of the wampum is for a symbol in the election of officers. The wampum bearer keeps the treaties of the nation."

This is not very clear by itself, but it has some reference to the following account of the Onondaga belts, given to E. W. Paige by Daniel and Thomas La Fort at Onondaga, July 19 and Aug. 1, 1898, and recorded by him in the appeal book in the Thacher case:

Fig 251 represents a sorrow meeting of the Five Nations. If a misfortune happen—little boys and girls were taken and one killed—to consider what should be done for remedy that misfortune—a tooth for a tooth, an eye for an eye. This is a Hiawatha belt. This belt is used when a meeting of that kind is called.

Fig. 232 representing a superior man—*To-do-da-ho*.—That is a

carpet for him to sit. You clean the carpet for him to sit and nothing evil can fall on the carpet. They have furnished two prominent women and having a broom so that it would be clean. This was in the lifetime of *To-do-da-ho*, and the Five Nations furnish him a stick, laying close by where he sits—represents as a limited power given to him by the Five Nations. If he sees something evil coming he would take the stick and throw away, and if the stick not strong enough then he would notify the Five Nations to come help him; that the animal and wild peoples come prepared for war. The *To-do-da-ho* would speak to the animal and ask: What is thy business coming here without our knowledge?

Fig. 252 One heart of the Five Nations—that if any hurt of any animal would pierce that heart, then they would all feel it—all the Five Nations. This was in *Hi-a-wat-ha's* belt. That they are a united people. This is the original *Hi-a-wat-ha* belt—a record of the first agreement to make the league.

Fig. 244 Between Bastable building and the corner of Genesee and Warren streets, Syracuse, was held the last council which completed the league. Both *Hi-a-wat-ha* and *To-do-da-ho* were there. 300 years (ago).

Represents an everlasting tree—always keep growing, reaching to heaven that all nations may see it; and under they set a general fire to burn forever—the council place of the Five Nations—and that the council fire is to be kept at the Onondagas, and the Onondagas are the expounders of the law.

After they had ratified—it was understood—we look far away and we see a darkness, and in the darkness an unknown and strange face, and they could not understand what it was—and it came to be interpreted that we would be forced to adopt an unknown law—but it was coming before that generation passed away, and finally their heads would roll and roll away, and after a time they would recover their bodies, and then they would embrace the law that was once lost to them, and the tree would grow forever. After they will restore the original law their confederation will be more permanent than the first one, and their original law will remain forever. They say that one of the women said: "You can use all the water of the ocean to wash away the Indian blood, and when you have done there is just as much water left in the ocean as before you began—so the law—you can take from it parts of the Indian law, and put another in its place, but it will come again and last forever."

This was the last belt that was made at that ratifying time. When the belt was ready it was said by one of the orators to that council, "This is the last belt which we make confirming the laws which we have just adopted," and he encouraged the people of the Five Nations to instruct them with the meaning of the wampum to serve

the laws. At the conclusion of his remarks he said: "As long as you will follow up the laws of the Five Nations you will be in prosperity and happiness, but whenever our people may not heed the instructions which we instructing to you, then it will come in the state of dissension among our people—and the last remark—if you will disobey and disregard the laws we have, that generation will suffer." *Hi-a-wat-ha* made that speech.

This belt is not the original which was there at that time, but a copy. It was made not a great while after the death of *Hi-a-wat-ha.* That each clan shall be entitled to one principal chief and war chief. When the council ended, *Hi-a-wat-ha* went up the Onondaga creek and distributed the belts among the clans—making the clans and chiefs. And in his speech he said: " I have made a place for you under ground and a fishing ground. I have finished my work." It is claimed that he did not die, but went up in his canoe and said: " When you shall be in a state of confusion I will come back."

That *Hi-a-wat-ha* saw the strange face in the midst of the darkness, and he interpreted it that the unknown law which was coming, should prevail over the new law—that is, the law which has just been adopted and the tree that was just planted. The root spread from east to west, and from south to north. Under the tree, while the root of the tree was spreading, all the Five Nations laid their heads on the root. That is the constitution. If any of their enemies should attempt to strike against the root—from their enemies destroying some of their people, and after striking against up the root, the man who struck the root would turn, and the blood would come out of his mouth. That is revenge for blood. The roots of the tree would continue spreading in all directions forever; and the fire would continue forever, and the smoke of it go all up to heaven, so that all the nations of the world would see; and that the laws—that is the wampums—be read every year forever. Between the Bastable and the corner of Warren and Genesee streets—last council.

Hi-a-wat-ha would come again, but when he did not say. He did not die, and when he came again he would renew the old, and it would be stronger than then, and that is the expectation we have. The former meetings of the Five Nations were on Onondaga lake, and some near Liverpool. He was the proclaimer of councils, and the only proper person to call a council. These wampums were made during these meetings, and were complete at the last meeting when everything was ratified.

The place mentioned in Syracuse was then a dense swamp. According to Morgan and Hale several clans had no principal chiefs. The Onondagas now generally agree with the writer that Hiawatha

lived about 300 years ago. He did not, however, go up Onondaga creek with the belts; for the Onondagas did not reach that valley till over a century later.

Fig. 236 This belt was made great many years afterwards. It is the Caughnawauga belt. This represents the union of the seven nations; the St Regis and Caughnawaugas—and the crooked line at the bottom represents that they were crooked—that is, Roman catholic.

Fig. 248 This is the record of the treaty with General Washington.

Mr Paige refers this to a treaty of 1789, between the United States and Six Nations, printed among the United States treaties. J. B. Thacher has this fine belt.

Fig. 237 A record of this: The priest told the Onondagas that a building right by the mission house—and told them that there were goods there stored for the Onondagas, but he could not open them until the king came, and a white boy who had been captured had been told by the priest that it was full of arms—and when the king came they would annihilate the Onondagas. The boy told the chief, and they held a council and resolved to open the building. The priest tried to keep them from it, but they opened the door in spite of him, and found the building full of arms. They heated an axe red hot, and hung it upon the priest's heart, and it burnt his heart out. The French did come, and the Onondagas met them at Camden, and defeated them in a great battle, and then the Onondagas all renounced catholicism.—It was between Pompey and Jamesville, about this side of Pompey Hill. Cross means Canada. The white line a road from Canada to the Onondagas and the village at the other end.

These symbols are correct, but the only historic truth is that of the almost bloodless French invasion.

Fig. 239 This belt was used to call a meeting of the council of the Five Nations, at which should be read all the laws. This was made when *Hi-a-wat-ha* was traveling and distributing the clans, and this belt made to represent that the nations were divided into clans, and were to remain strictly so—that there could be no intermarriage. This last was said rather as a detail.

Fig. 240 The five upper diagonal rows are the *Hi-a-wat-ha* belt, and represent the union of the Five Nations. When the Tuscaroras were taken in they added the sixth, which they call a brace. This is the taking in of the Tuscaroras.

This interpretation is baseless. The belt had seven diagonal rows when first seen by the writer, and was even then defective at both ends, probably having as many as 10 bars.

Fig. 238 Braces to buttress up a house so that it would not fall. Made when the St Regis were taken in—so that the St Regis were a brace to the Five Nations, and the Five Nations to the St Regis.

Fig. 249 A record of the first coming of the people with white faces.

Fig. 250 shows what remained of an Onondaga belt in 1878. This fragment has long disappeared. This steady waste of the belts caused an effort for their preservation. By council action at Onondaga the regents of the University were made keepers of the wampum, and at a council in the capitol at Albany, June 29, 1898, the Iroquois chiefs of New York placed in their hands all the belts that remained. The meeting was held in the senate chamber, and the proceedings were impressive.

Figures are given of 11 belts belonging to Thomas W. Roddy, of Chicago. They are mostly fine and in good preservation, but erroneous dates have been given to some. In fact a good authority reports them as having recently belonged to the Canadian Six Nations. Fig. 185 is called a "French peace belt, 200 years old," but without particular reason. It may be a covenant belt of half a century later, or a proposal for an alliance. The single line seems the path of peace, and the five long open figures are probably the Five Nations, while the four uniform white diamonds may be four of the colonies of the white settlers. This is the largest belt in this collection, but does not equal many others in size, being 14 rows deep and 500 beads long, an unusual length now. The material and symbols make its recent date probable. Fig. 184 is called a French mission belt by the owner, apparently because of the crosses. This is a plausible but not certain test, and it may be considered about the age of the last. Fig. 180 is called the Red Jacket belt, and the owner says that "it contains pictorial representations of the nine council fires in which he took part during his life." It might bear this interpretation, as the diamonds may mean fires, villages or nations, but the Seneca orator can hardly be limited to so few councils. The usual interpretation would be an alliance between nine towns or nations. The belt is 15 rows, with a line and diamonds of dark wampum on a white ground.

Fig. 186 is styled the "Captain Brant belt of 1750." The great chief was then a child of 8 years, and a belt of that date could have had no reference to him. Still less can it be allowed that "the three white lines on his wampum show his trips to England." He made but two trips there, not three. There is an open square at each end, signifying a nation, while the broad white line between shows an alliance both strong and enduring. Fig. 183 is called a Black Hawk belt, and is a black belt 12 rows deep. Seven open diamonds of white beads are united by a line of white, indicating a covenant.

Fig. 187 has the double diamonds found on some others. There are five of these in this, and they may well stand for the Five Nations. The owner thought so, and called it "Five Nations' war belt." By the use of red paint any belt acquired this character. It is 15 rows deep, and has some short white rows at one end. This may be compared with a similar New York belt. Fig. 191 is defective, but has two white squares and two white hexagons, inclosing similar figures. It is styled the "Old French fort belt of New York, 300 years old." No French fort was here then. It seems quite a recent belt.

Fig. 189 has been called the "Six Nations' peace belt." It has partly open diamonds on a white ground, and is 10 rows deep. There is no symbol to indicate this character. Fig. 188 is also styled by the owner "Six Nations' peace belt, representing two roads." He interprets it as an offer of peace from the Americans and English respectively, either of which the Indians might choose. Fig. 190 he considers the Gov. Denny belt of 1758, inviting the Indians to a council at Philadelphia. It does not seem probable that an invitation belt would have survived so long, and the figures are those of a covenant, more likely to be preserved.

Fig. 192 evidently refers to a council, and Mr Roddy calls it the first William Penn belt. A statement connected with it says that the belt was given to the Indians "before they entered the council house where the treaty was to be made, and was a token of amity and good faith. On the belt is worked the figure of a white man and one of an Indian. To distinguish one from the other the white

man is marked with a white heart, and the Indian with a dark one. When the treaty had been concluded, and the Indians came out of the council house with Penn, they presented him with a return belt as evidence of their good faith." The usual idea is that the treaty was under a tree. The house is imaginary, but the general character is much like that of the noted Penn belt; strictly the style of a later day. Thanks are due Mr Roddy for photographs of all these fine belts, which are of great value, though of uncertain age.

William C. Bryant, of Buffalo, writes of two belts in his possession: "The large belt was read in the last great Canadian council at the Grand River, in the 70's, being a treaty belt representing an Iroquois and a white man clasping hands from opposite sides of the belt. The second and smaller belt, consisting entirely of dark beads, was the credentials of a runner sent to convene a war council. I believe both belts were ante-revolutionary. I have a volume containing the proceedings of the above mentioned council, and the reading of the belts."

W. L. Hildburgh, in a recent letter to the writer, said: "While in Rome I heard of what may be a large wampum belt in the museum of the College of the Propaganda Dei Fides. My informant spoke French to me, and was not versed in American archaeology, so that I may be mistaken." On farther inquiry it did not appear.

Mr Hildburgh made small photographs of four belts in the museum of the Trocadero, Paris. One was lettered. Fig. 272 represents another of eight rows, about 224 beads long, with purple *swastikas* on a white ground. Fig. 273 was called a scapular, but it may have been merely an exceptional form of belt. The general pattern is of hollow squares and crosses. In the widest part it has 13 rows, and is about 260 beads long. Fig. 274 is 17 rows wide, and about 225 beads long. There are Indians with bows in white on a purple ground, unusually arranged.

He has also added another too late for illustration. He describes it as a Huron wampum belt in the Imperial museum of natural history, Vienna, Austria. It is a white belt, with five double diagonal black bars, thus suggesting the Five Nations rather than the

Hurons. It is 10 rows deep, and can easily be figured from the formula of the upper row: 16 white, one black, two white, three black, 20 white, one black, two white, three black, 20 white, one black, two white, three black, 21 white, one black, two white, three black, 21 white, three black, two white, one black, 21 white. In each succeeding row move the black one bead to the right, making the lower row begin with 25 white beads.

Fig. 255 may be compared with one of these belts. It is taken from a picture of one of the Mohawk chiefs who went to England in 1710, and has two rows of hollow crosses on a purple ground. The extreme length would be about 3 feet, and the width is estimated at 20 rows. The crosses may refer to part of their mission. This is from the picture of "*Fee-yee-neen-ho-go*, (*Tekarihoga*) emperor of the Six Nations."

In 1895 S. H. Goodwin sent the writer three small belts for examination, which he had from near the Georgian bay, Canada. Fig. 254 shows one of these, being an ordinary belt of seven rows, having five rows of white beads arranged diagonally on the dark ground. The others were of unusual form, an expanding basket shape, broad at the top. Fig. 169 shows one of these 28 rows deep, having five open white diamonds on a dark ground. Fig. 170 is of the same general form, and is 27 rows deep. It has nine open squares of white beads arranged diagonally. The foundation of both is of twine.

The writer attended a council at *Ohsweken*, Canada, in 1899, and secured pictures of the belts there. Fig. 174 is six rows deep, and has 11 broad vertical bands of black and 10 of white. Fig. 175 is of 12 rows, mostly white. There are three double diagonal bands of black, one and four beads wide. Fig. 176 is seven rows deep, with 10 broad, black, diagonal bands, and the same of white. Fig. 177 is of eight rows, mostly white, with five triple diagonal bands, two of one black, and one of three black beads. Fig. 178 is of seven rows of white glass beads, perfectly plain. Fig. 179 has nine rows, crossed by three double diagonal rows of single black beads on a white ground. After John Buck's death most of the fine collection of Canadian Iroquois belts quickly disappeared.

Some additional belts in the state museum are to be described. Fig. 229 is a fine emblematic belt, with a wolf and black horizontal bars at each end, and two men clasping hands in the center. It is 14 rows deep, and mostly of white beads. It has been called a Mohawk totem belt, and was bought at St Regis, July 24, 1898, by Mrs Converse. She writes: " Date unknown. Purchased from a St Regis Indian, and known as the Wolf belt. Supposed to be a treaty between the French and Mohawks. The center figures—two men—represent the king and an Indian clasping hands in friendship. The seven purple lines signify seven nations, white the peace paths guarded at each end, east and west, by sachems of the Wolf clan, symbolized by the purple animal figures. The hereditary keeper of the eastern door of the Long House was a Wolf, the *Do-ga-e-o-ga* of the Mohawks according to John Buck. The *Do-ne-ho-ga-weh* of the western door was also a Wolf." The Mohawk chief mentioned was a Turtle, but the Seneca chief is correct. The Mohawks treated with the French, but were never in their alliance, and the emblems are those of the middle of the 18th century. At that time the western Iroquois were balancing between the English and French.

Fig. 234 is of 10 rows, mostly white, but with three diagonal rows of three open, black squares. This is recorded as a " Huron belt purchased from John Buck, the wampum keeper of the Grand River (Ontario) Canadian reservation. Chief Buck said that the belt had originally belonged to the Senecas of New York, and, previous to the revolutionary war had been in their possession. The Hurons were exterminated by the Iroquois in 1650, and, as the belt contains braces, it is to be inferred that it was wrought for some time previous to the extermination of the 'gentle' Hurons. This belt may have been an affiliation between the Hurons and some of their neighbors, the Wyandots, *Quatoghies*, Neuters, *Ka-kwas* or others." The Hurons rarely used treaty belts before their overthrow, but were fond of them in later years. The belt, if Huron, may be assigned to their later days.

Fig. 235 is a long and narrow purple belt of seven rows. Mrs Converse writes: " This is a condolence belt, with two diamonds

and a half circle in white. This was marked Onondaga. It was purchased by me as such, but I now find it was a Seneca belt, and Gov. Blacksnake held it." Fig. 242 is a white belt of six rows, with three diagonal bars of black. It is labeled a "hospitality or welcome belt—Canadian Mohawk." Fig. 247 is entitled a "ransom belt." "Could save a life if presented by the youngest unmarried female in the family." It is a purple belt of six rows, with white diagonal lines and open hexagons.

Fig. 246 is of much interest. It is nine rows deep, and has six human figures in black, joined by a dark line. Midway is the council fire. Mrs Converse obtained this in 1882, of Martha Hemlock, an aged and prominent Cattaraugus Seneca, who had it for 60 years. It has been called the women's nominating belt, they having the privilege of naming the chiefs. This is now done with strings or unceremoniously, but women's belts for other purposes are on record.

Fig. 172 is a Mohawk belt from Mr Holmes's figure, and was obtained by Mrs E. A. Smith from the Mohawks. It is 26 inches long, with an extreme width of 3 inches, or 11 rows. The design is curious, and suggests one of the belts in Paris. From the center it diminishes in width toward one end, where it is five beads wide. The open white hexagons show that this was probably the original design. A doubt is suggested by the loose buckskin thongs. It may once have been symmetric, having the other end correspond beyond the open central space.

Walter C. Wyman, of Chicago, furnished pictures of his seven interesting belts. Fig. 274a, he remarks, "is called the Sir William Johnson dish belt, sent by the Indians in Canada to notify the friendly tribes of the existence of food at four points, Forts Stanwix, Niagara, and two other points unknown to me now. Of course all these points of information are fragmentary and dreamy, but are as they came to me. There seems to be no authentic reading of belts, and their mission is imaginary so far as any present day interpreter is concerned." This is a counterpart of the Parker belt, except in the number of hexagons and width, having nine rows. In some cases the Five Nations used but four of the national figures, as in this case.

Fig. 275 is a defective white belt of 15 rows, with one small, open diamond and four large. Mr Wyman said: "This I secured from an Indian at the ancient town of Cross Village, Michigan. It was called by him a Mohawk peace belt, but I could get very little information from him."

Fig. 276 "is the Black Hawk belt, sent by this noted chief to the tribes at Traverse bay, Mich., with a message that their band should remain neutral during the campaigns and revolts at Michilimackinac." This has the frequent double diamonds on a dark ground, and is 10 rows deep.

Fig. 277 is a very fine Oneida belt of unique character, and 21 rows wide. The design suggests Grecian art. Six double squares of white beads are united, and six white diamonds are in the center of these. It is nearly perfect. The owner says: "This was long in the possession of chief *Skenando*, probably his lifetime, and came to him from the old chief *Skenando* before him, as a silver pipe was kept with the belt, inscribed to 'Skenandoah,' presented by Gov. Tompkins of New York. . . . The belt has been known as the tribal belt of the Oneida tribe, and, farther, the legend went that without this belt no council of the Six Nations could be had, or was official. The belt is well preserved, woven with sinew, the beads have a high polish from ages of handling, and I conclude dates back at least two hundred years." The six diamonds probably included the Tuscaroras, who lived in the Oneida territory, and were thus more likely to appear on an Oneida belt than elsewhere, but, as they came to New York about 1712, this would make the belt of later date. Skenandoah was not prominent in the colonial period, and the writer is inclined to make it as late as the revolution. The silver pipe was the old chief's pride.

The following three are Penobscot belts. Fig. 279 is said to have "belonged to Molly Molasses, sent to her parents from the young buck's parents that wanted her in marriage. Molly was one of the characters about Oldtown, Maine, looked on as the medicine woman of the tribe. She lived to be 92 years old." It is a defective belt of seven rows of dark beads. Part of the white pattern suggests letters.

Fig. 278 and 280 are of a very novel character. They are of dark beads edged with white, and the rows cross the belt diagonally instead of the usual way. Fig. 278 has velvet strings, and fig. 280 has elliptic beads on one border. Mr Wyman said these "are called marriage belts, and came to me directly from the families to whom the belts were descended by marriage, passing from generation to generation at the marriage of the oldest child. The outer edge of one of the belts is made from a different variety of seashell, the only ones I have ever seen. The three belts came from Mrs Lizzie Nicola, one of the old-time Indian families of the Penobscot tribe."

Acts with. The French always termed wampum belts collars of porcelain, and they were used in many ways. Among the Hurons in 1636 they appeared among the stakes when the ball game of lacrosse was played. The Algonquins had ceremonies much like other nations in reviving or raising dead chiefs and warriors. As long ago as 1639, when a Canadian Algonquin had been killed, if he had a wampum belt or other article of value, it was offered to some good warrior. If he took it with the name of the deceased, he was expected to go to war and kill or take some one in place of the dead man. In a different way at Oneida in 1756, Johnson gave a belt to the chief warrior, "insisting (according to the Indian Custom), on his going to war, and bringing him either prisoners or scalps to give in the Room of some friends he had lost." This act is somewhat related to the council of condolence.

When the Iroquois chiefs were at Albany in 1746, "they threw down a War Belt of Wampum on the Ground, it being the Indian Custom to deliver War Belts or make Declarations of War in that manner, this they did with remarkable Indignation intending thereby to express their Resentment against The French and their Allies, and their Zeal for the English." This act was not confined to war belts. At Canajoharie, Ap. 13, 1759, Johnson gave the Six Nations a very large black belt relating to a murder, which was answered three days later. "The Speaker then threw on the ground towards Sir William the large Belt which he gave on the 13th Inst. in a manner which according to the Indian customs was

expressive of the sincerity of what they had declared." If a proposition was not liked, the belt might lie for hours or days on the ground. To raise it was to accept the proposition. Loskiel said that, if peace proposals were rejected, "when the ambassadors return home with the refusal, the Delawares throw the belt or string of wampum thus rejected into the council house, and there it lies till some old woman takes it away."

Sometimes the rejection was vigorous. In 1691 the Five Nations rejected a French belt while at Albany. "We declare the belt of wampum given by the French venomous and detestable, and did spew it out and renounce it, and will not accept of the belt but prosecute the war as long as we live; and left the belt upon the ground in the court house yard." In 1693 imperious Count Frontenac kicked away three belts sent him by the Five Nations, and five years later flung a belt in the faces of 10 Onondaga messengers. They retorted in kind when he sent them five belts in 1699. A sachem asked for them in the council at Onondaga, "and one of the sachems got them and threw them towards him, but not so far as that sachem sat, and another Indian very scornfully kicked them at him." Quite as vigorous was the reception of the war belt which Johnson gave in 1756. "A Seneca chief laid hold of it, sung the war song and danced," and it passed on to others.

Attachments. Belts often had something attached. After the treacherous seizure of the Iroquois by De Nonville a Cayuga chief addressed Gov. Andros in 1688. "Hee presented a Belt of Wampum, with twentyeight sticks tyed to itt, to shew the number of the Indians taken by the French." At an earlier day, when Chaumonot came to Onondaga in 1655, for his second present he "made a crown of a collar, which he presented them and placed it on the head of one after another. They were at first surprised at this novelty." He made over 30 presents at one council, but the present of the faith was "the most beautiful of all which the father showed." His ninth present was a tree appropriately prepared, lopped branches showing dead chiefs and growing boughs their children. "They regarded more attentively this piece of wood than the porcelain which was attached to this present."

In 1745 Gov. Clinton gave the Six Nations "a large Belt with the figure of a Hatchet hung to it." In 1757 Sir William Johnson gave them a large belt, with the seal of his office on a parchment tied to it. The same year while in Canada the Oneidas presented the Cayugas with a belt and an English scalp attached, English scalps never before having been in the Cayuga cabins. Scalps were often attached to belts, and scalp belts were given in place of Indians killed. At Oswego in 1766 an Onondaga chief gave a Cherokee scalp to Johnson, "after painting the scalp belt of wampum which hung to it." On the death of the Half King in 1756, a stick with an Indian scalp and two black belts at the end, was presented at Carlisle. Several examples of attached belts occurred that year in Pennsylvania. Two belts and two strings tied endwise were used on one occasion, and a belt of eight rows had two strings attached on another. The same year at Easton two belts tied together signified that *Teedyuscung* and Newcastle were joint agents. The former chief, at the same place the next year, gave a belt of 12 rows strung on cords, and also two belts tied together, with an explanation of the ancient mode of making an everlasting peace. In 1765 Pontiac sent his large pipe to Johnson with a belt attached, calumets being highly esteemed by nations farther west. In 1768 the Cherokees gave belts and calumets. One belt had a calumet and eagle's tail attached.

One curious mention of a chain belt occurs in the Paris documents. In 1682 Count Frontenac's third word to the Iroquois deputies was the "third belt of wampum in the form of a chain." This may refer to a primitive method of making these belts by tying strings together. A yet more puzzling statement relates to the council at which Fort Frontenac was founded in 1673. The chiefs addressed the count in turn, and "each captain presented, at the conclusion of his speech, a belt of wampum, which is worthy of note, because formerly it was customary to present only some fathoms of stringed wampum." Such large numbers of belts were described before this that the comment is not easily understood.

Belts were often doubled, one message being given in this way,

after which the belt was unfolded and another message was added. In one case the river Indians presented Gov. Fletcher with half a belt of wampum in 1693. *Arratio* spoke for the upper Iroquois to Frontenac in 1697. His second belt was divided between two messages. By one half he expelled sorrow from *Onnontio's* heart; by the other he arrested the hatchets of the young Onondagas. To three strings of wampum, each bearing a message, Count Frontenac joined a belt to the Onondagas in 1697. Each half of this carried a message. "The belt was folded double. The one halfe was a token of the affection he had for *Odatsigtha*, and the other halfe was to show the Five Nations the inclination he had to make peace with them." The Onondagas resolved to send two chiefs to Canada "with a belt of wampum folded double."

Colden gives the only account of the great council held at Onondaga in January 1690. The principal Iroquois chief held one of the belts sent by Frontenac, by the middle, and gave one message. Then he said, "What I have said relates only to one Half of the Belt, the other Half is to let us know, that he intends to kindle again his Fire at Cadaraqui next Spring." A captive Cayuga chief sent a number of belts at this time, one of which was folded. His address appears without date in the *Documents relative to the colonial history of the state of New York*. The greater prominence of belts of this kind in Canada was probably due to the scarcity of wampum there, all of this coming from New York. Indeed Frontenac according to his enemies did not approve the use of wampum. In 1679 they wrote to France of what he did when the Ottawas brought beavers to trade. "The Indians having included in their presents to the governor some old moose hides and a belt of wampum, which they appreciate highly and which the French do not value as much as they do beaver, he caused his interpreter to tell them, according to their mode of speaking, that such did not open his ears, and that he did not hear them except when they spoke with beaver. This the Indians were obliged to do in order to have liberty to trade." The same writer said that a *coureur de bois*, whom Frontenac favored, took beaver skins to Albany in order to get wampum to trade with the Ottawas.

While David Zeisberger was at the Monsey town of *Gosch-goschünk* in 1768, a mysterious message came from the Senecas, opposing him. It was accompanied by "a string of wampum, a stick painted red, with several prongs, and a leaden bullet." Another followed with "a bunch of wampum, or as many strings as a man can hold in one hand."—*De Schweinitz*, p. 342

R. C. Adams, a Delaware of the Indian territory, relates a story of an early belt in the *Report on Indians taxed and not taxed*, p. 298. Though apocryphal, it is none the less striking.

Many hundred years before the white man came to what is now the United States, a treaty of friendship was made with other Indian nations, and in memory of that event a wampum belt was presented to the Delaware chief, with a copper heart in the center of it. That belt was seen and acknowledged by William Penn, afterwards by British generals, later by Gen. George Washington, and from that down to about 45 years ago, 1841, by every Indian tribe in the north and east. In presenting the belt at a grand council the Delaware chief would always hold it out, and ask if any one could detect any change in the heart, whereupon it would be passed from one chief to another, and from one brave to another, and returned, and each chief would respond that the heart had remained unchangeable and true, although the sinews that held the wampum may have become rotten with age, and had to be replaced with new ones. Although a wampum may have fallen off and thereby a figure in it been changed, yet the heart was always just the same. After exhorting for a time on the subject they would renew their bonds of friendship, smoke the pipe of peace and depart. From what I can learn, Captain Ketcham had this wonderful belt when he died in 1858. My informant thinks it is in the possession of the Delawares who are now with the Kiowas and Wichitas.

It is a pity that this pretty story has no historic foundation, and could not have been true as far as age is concerned.

In his *History of Jefferson county*, p. 39, F. B. Hough says that the Oneidas, "by a definite treaty held in September 1788 conveyed the greater part of their lands to the state by the following instrument, the original of which is preserved in the secretary's office; it is on a sheet of parchment about 2 feet square, with 35 seals of the parties; appended to it is a string of wampum, made of six rows of cylindrical white and blue beads, strung upon deerskin cords. This

belt is about 2 inches in width, and nearly 2 feet long." As this was written in 1854 by a thoroughly competent person, it was thought that an illustration of this attachment might be readily procured. On application it was found that the parchment and belt had disappeared, a copy filling the place of the former. The practice of attaching a belt as the seal of a treaty seems to have been common here after the colonial period.

Abundance. The size and abundance of belts form a notable feature. In Canada the supply of wampum was naturally smaller than in New York, but still it might be called large till the Iroquois overthrew the Hurons and the Tobacco and Neutral nations. A small nation on the Ottawa river levied toll on all travelers, and they were known as Savages of the Isle. Out of these gains they were able to present the Hurons with 23 porcelain collars in 1636, and as many elsewhere, in asking aid to revenge the loss of 23 of their people, killed by the Iroquois. The presents were refused. The wampum or porcelain used by the Hurons in personal decoration may have been larger beads. Belts were less in use by them. When they sent messengers to the Andastes in 1647, "that they might have pity on a land that was drawing to its end," no belts are mentioned. Instead there were "the most precious rarities of this country, which our Hurons had taken to make a present of them, and say that it was the voice of their dying fatherland."

This difference came out more plainly when they replied to the Onondaga embassy in 1647. The Huron ambassadors "carried like presents in reply to those of the *Onnontaeronnon.* Our Hurons use for these presents peltries, precious in the hostile country: the *Onnontaeronnons* use collars of porcelain." The Onondagas sent a new embassy with the returning Hurons. "Beside the captives that Jean Baptiste was taking back he was loaded with seven great collars of porcelain, each of which was of three and four thousand beads." These were new presents.

Leclerq says that in 1617 the Indians offered a number of wampum collars to light a council fire at Three Rivers and another at Quebec. They gave at the same time another present of 2000

beads to serve as wood and fuel, and added a large belt to these.— *Leclerq,* 1:126. A similar incident is related of the Mohawks in 1646; and this writer seems to have mistaken the date. The Algonquin use of belts in Canada is often mentioned. To some extent this family used wampum in this form in New York. Among the plunder in one Indian fort in the Esopus war of 1663 were 31 belts and some strings of wampum.

Negotiations with the Iroquois brought a great deal of wampum into Canada. When the Mohawk chief, *Kiotsaeton,* came to Quebec in 1645, "he was as it were covered with porcelain." He brought 17 collars or belts, part on his body, part in a little sack. Of the 10th belt it is said, "this collar is extraordinarily fine." By the 13th he referred to some Huron preparations for peace proposals five years before, when that people "had a sack full of wampum all prepared to come to seek the peace." This they should have done. After this Mohawk belts often came to Canada in a less formal way. The same year ambassadors brought 18 of these. The first Onondaga presents made at Quebec in 1653 were but seven in number, and consisted of wampum and beaver skins. A great belt from the Oneidas accompanied these. At the same time the Mohawks made eight presents. The next February the Onondagas came again with six great belts for the French. They secretly gave four others to the Hurons. This was preliminary to another council in May, when the Onondagas presented 20 belts to confirm the peace. Father Le Moyne's first visit to that people soon followed. After he had made his 19 presents, the Onondaga speaker returned thanks for the Onondagas, Mohawks and Senecas by two great belts for each. An Oneida chief also returned thanks by four great belts.

In September 1655, another Onondaga embassy came with "24 collars of porcelain, which to the eyes of the savages are the pearls and diamonds of this land." Chaumonot and Dablon returned with this party and made their presents. The Onondagas replied, casting their first two presents at Chaumonot's feet. "The third and the most beautiful of all those which appeared here, was a collar composed of seven thousand grains of porcelain, which was as

nothing in comparison with his words." Four great belts were given. Others followed from a Cayuga chief. During the stay of the French colony at Onondaga lake, one of the most touching incidents was the presentation of eight belts by the Onondagas, on the death of two Frenchmen in 1656. This was in keeping with their usual customs, for " these nations make each year reciprocally presents of friendship in the councils and public assemblies."

It will suffice to mention a few out of the many belts recorded in the Jesuit *Relations* and in various colonial documents. In 1646 Father Jogues gave a belt of 5000 beads to the Mohawks, to break the bonds of a French child, and another for the deliverance of a Huron girl. He also gave some Onondagas 2000 beads to announce the coming of the French. In 1661 a Cayuga ambassador came to Montreal and "displayed 20 beautiful presents of porcelain, which spoke more eloquently than he, though he failed not to speak with good grace, and to deduce all points of his embassy with spirit." When *Garakontié* arranged an embassy of Onondagas and Senecas in 1664, he " made for this a prodigious collection of porcelain, which is the gold of the country, in order to make us the most beautiful presents which had ever been made us. There were among others a hundred collars, of which some were more than a foot wide." The embassy was attacked and scattered on the way to Canada.

Among belts sent by the French in 1670, on account of the murder of some Oneidas and Senecas, the most beautiful was one of 5000 black beads intended for the latter nation. The murderers were punished; but the missionary shrewdly adds, "They approved of the governor's justice, but I nevertheless believe that they would have better liked 10 collars of porcelain than the death of these three Frenchmen." Chauvignière, called *Raghquanonda* by the Indians, brought a French belt to Onondaga in 1747, which was 7 feet long and 6 inches wide. The Iroquois presented several belts at Albany in 1682, which were 15 and 16 rows deep. In 1713 four southern nations came to Onondaga with 20 large belts and six strings, and sent 10 more belts the next year. The Nanticokes sent

a belt to the Delawares in 1756, which was a fathom long and 25 rows wide. Both these nations paid a large annual tribute of wampum to the Five Nations, amounting to a score or more of belts from each. Many of Johnson's belts were quite large, and in 1756 the Mohawks gave him one which was called a broad belt. No belts on record were as wide as two now in the state museum. Though there are a few instances of very wide belts, it is probable that, where large numbers were brought together, the usual length and width prevailed. Perhaps the council of Scioto of 1771 alone rivaled *Garakontié's* collection, as a hundred belts were ready for this some time before the council met.

There are more belts now in existence than is commonly supposed. Several have come to the writer's notice, and David Boyle writes him that of recent Canadian ones "some 50 or 60 belts and strings have disappeared," and sensibly adds: "One answers our purpose as well as a dozen or a score." This philosophic remark may be qualified by the fact that belts vary much in form and symbols, however rarely their history can be traced. No one will object to a good supply.

Uses of wampum

Wampum was used in many ways. In 1646 the Mohawks "offered a fathom of wampum to kindle a council fire at Three Rivers, and a great collar of 3000 grains to serve as wood or fuel for this fire. The savages make no assembly unless with a calumet of tobacco in the mouth, and as the fire is necessary to take the tobacco, they almost always light some in all their assemblies."—*Relation*, 1646. This seems the circumstance mentioned by Leclerq, as occurring much earlier, but in the same words. (*Leclerq*, 1:126)

In 1657 a returning Onondaga war party was "regaled with many thousands of porcelain." At the same place in 1670 Father Milet used wampum in teaching. "During one week I placed before their eyes different strings of porcelain to mark the number and diversi-

ties of the things I was teaching them. . . At other times I suspended by the same cord a beautiful collar of porcelain before the altar of my chapel to teach them that there was only one God. . . Some strings of bugle beads to explain the liberality of which Heaven made use in rewarding all good actions."—*Relation*, 1670. He used these as rewards himself.

It was noted of wampum and other presents in 1665: "They give to each of these presents a name, very fitting in their tongue, to signify in brief all that they wish to say, in order that those presents which they preserve may also preserve, by this name, the memory of the things which they signify." In 1656 it was also said: "Each present has its different name, according to the several effects which they claim to imprint in their minds and in their hearts." In accordance with their ideas of the soul, "they usually make one present to put back the reasonable soul in the seat of reason."

In the account of a conference at Montreal in 1756, it is said in a note:

These belts and strings of wampum are the universal agent among Indians, serving as money, jewelry, ornaments, annals, and for registers; 'tis the bond of nations and individuals; an inviolable and sacred pledge which guarantees messages, promises and treaties. As writing is not in use among them, they make a local memoir by means of these belts, each of which signifies a particular affair or a circumstance of affairs. The chiefs of the villages are the depositories of them, and communicate them to the young people, who thus learn the history and engagements of their nation. *O'Callaghan. Colonial hist.* 10:556

While all presents had names and meanings, it was observed in 1642 that three belts were often given in freeing a captive, in order to break his three bonds, the legs, arms and waist. This was not a ransom, which was more personal, but was the gift of the nation setting the prisoner free. This was among the Algonquins. In raising or reviving a chief the Hurons made presents for the principal parts of the body.

As the Indians enjoyed fun, the Delawares threw wampum on the ground for a scramble at some of their feasts. The Hurons had a funeral game for prizes, much like the college cane rush. At the *Nipissirinien* dead feast in 1642, still farther northwest, the bones

of the dead were "inclosed in cases of bark, covered with new beaver robes, enriched with collars and scarfs of porcelain." While wampum was among the funeral presents, the prizes on the greased pole were a kettle and a deerskin.

A picture of an early New York council is taken from the second English edition of Baron La Hontan's travels, and the wampum belt in this does not differ from later examples. M. De la Barre came to the mouth of the Famine, now Salmon river, in 1684, and held a council with the Onondagas. *Hotreouati*, called Garangula by Colden, was the Iroquois speaker, and his sarcastic address is famous in the annals of Indian oratory. It has been questioned whether La Hontan was really there, as his name does not appear in the list of officers. Few of these were mentioned, and he was then not 17 years old, and had been less than a year in Canada. In later days he was given to romancing, and this has thrown discredit on other things. The question is whether this is a true picture of the only council held by a French governor on New York soil. Fig. 282 shows this.

La Hontan used the name which the French had given the Onondaga orator. He mentioned the positions of the two principal actors. "The Grangula sat on the east side, being placed at the head of his men;" that is, in front of them to the east. De la Barre "sat in his chair of state," on the opposite side, and in front of his tent. This required a camp on the north side of the river, which flows into the lake from the east. On that side the writer found high sand dunes where the camp is placed in the plan, and a level space where the council is represented near the lake. The picture may be accepted in its main points, and in the council belts were freely used. The plan is given for its local interest. The orator holds the calumet. Lafitau represents another council where belts are held.

In councils and elsewhere significant acts often accompanied the use of wampum. When visiting Canada in 1645, the Mohawk chief *Kiotsaeton* attached a belt to the prisoner Couture's arm, with an expressive pantomime, and then gave him his freedom. To show his friendly feelings, he afterward bound himself to a Frenchman

and an Algonquin, with an unusually fine belt. At a later council, that year, a Mohawk "took a Frenchman on one side, an Algonquin and Huron on the other, and holding them bound with his arms they danced in cadence, and sang a song of peace with one strong voice." This kind of pantomime was strikingly employed at the reception of the French at Onondaga in 1655. With his third present *Garakontié* took Chaumonot by the hand, made him rise and led him to the midst of the council. Then he "throws himself on his neck, embraces him, hugs him, and, holding in his hand the beautiful collar, making a belt of it for him, protests in the face of heaven and earth that he wished to embrace the faith as he embraced the father." A Cayuga chief also sang with his present. "He explained what he meant by his *Gaianderé,* which signifies among them very excellent thing. He said that that which we call among ourselves the faith, ought to be called among them *Gaianderé,* and in order the better to signify this he made the first present of porcelain."—*Relation,* 1656

The speaker held the belt while speaking. When the Rev. Mr Kirkland stopped at the Onondaga council house in 1764, one of the Indians with him rose and took the belt in his left hand, leaving the right free for gestures. He spoke for nearly an hour. "At the end of every sentence they expressed their assent, if pleasing to them, by crying out, one after another or 20 at once, *at-hoo-to-yes-ke,* i. e. 'It is so'; 'very true'."—*Lothrop,* p. 163. After this a response was made. At the Seneca council house the belt was handed round. Some stroked it with the hand and said a few words; others only looked steadfastly at it. This took full 20 minutes.—*Lothrop,* p. 167

These marks of approval were customary. The *Pennsylvania colonial records* describe the giving of a belt by the governor in 1731, as a league and chain of friendship with the Six Nations. "The Indians, on receiving the Belts of Wampum & the Present, expressed their Thankfulness by a harmonious Sound peculiar to them, in which those of each Nation now present joyned alternately, & they repeated the same with great Seeming Satisfaction."

Some peculiar forms were used in early councils which have not

yet fully disappeared. In a council held in the fort in Quebec in 1645, the hanging of wampum was described. " In the middle was a little space where the Iroquois had placed two poles, and stretched a cord from one to the other. Attached to this were the words they bore, i. e. the presents. There were 17 porcelain collars, partly on his body, partly in a little sack." The orator took a collar in his hand and spoke, and then promenaded and sang. Le Moyne adopted the promenade when he made his 19 presents at Onondaga in 1654. "At each of my presents they made from the bottom of the chest a powerful ejaculation as a testimony of their joy. I was the full space of two hours making all my harangue in the tone of a captain, promenading after their custom like an actor on the stage." A council was held with a New England nation at Quebec in 1652, in the Jesuits' hall. " They began by the exhibition of the presents, which they stretched on a cord which extended through all the hall. Those were only very large collars of porcelain, bracelets, earrings, and calumets or petunoirs."

This hanging up of presents is noticed by English writers. At a conference with Lieut.-Gov. Evans of Pennsylvania, in 1707, " a Nanticoke Indian took into his hands a Belt of Wampum from a Line, whereon there was hanging nineteen others, and several strings of Beads."—*Penn. Minutes*, 2:387. When John Bartram was at Onondaga in 1743, Conrad Weiser delivered three broad belts and five strings of wampum. " There was a pole laid across from one chamber to another, over the passage, on which the belts and strings were hung that all the council might see them."—*Bartram*, p. 60. Weiser also mentioned this. "All the wampum was hung over a stick laid across the house, about six feet from the ground." There are other obscure references to this. In 1699 Gov. Bellomont's propositions with " seven hands of wampum were hung up in the proposition house." Two years before Count Frontenac gave two belts to the Foxes on account of the killing of two of their chiefs by the Iroquois. These were " to hang in the cabin of the dead, and to remain there until this vengeance be consummated." The Iroquois naturally were pleased with attention to such forms, and expressed their gratitude to Sir William Johnson

in 1768 for observing one of their ancient customs. He had given them a string of wampum in a pouch.

One Iroquois custom was mentioned at a council in Montreal in 1756. "The Cayuga orator terminated the session by calling, in a loud voice, each nation according to its rank, and, when he named it, the chief thereof uttered the cry of thanks, which was repeated in cadence by all the Indians." This appears elsewhere, but not the rest. In regard to the belts presented by the Five Nations, "each of them furnished in turn and contributed equally to that expense, and as the Indians are very particular in exhibiting the share they possess in these presents, at the end of each speech, the orator is careful, when handling the belt, to cry out the name of the canton, or nation, which has furnished it."—*O'Callaghan. Colonial hist.* 10:563

Father Milet notes this feature in his interesting account of making ready for a council, which is contained in the second chapter of the *Relation* for 1673-74. He wrote from Oneida (N. Y.) and said:

In order to maintain peace among themselves and make amends for faults committed by individuals, the Iroquois nations have instituted certain embassies which they reciprocally send one to another. In these they exhibit their finest porcelain collars, with the utmost magnificence in their power; and their captains endeavor to display their eloquence, both in relating their fables, their genealogies and their stories; and in suitably exhorting the ancients and warriors, according to the exigencies of present affairs. In each family there are a certain number of men and women of note, who represent, as it were, the nobles of the land. These are called *Agoiandères*, and they provide the porcelain and the collars. When it is intended to send an embassy to other nations, the families first meet, each in private, and collect all the porcelain that they have to give; then each family displays to the others what the richest among them have supplied. Then the oldest or most eloquent of the family makes an harangue—either standing erect, or oftener walking about. At times he speaks in a lugubrious tone, drawling out his words; at others in a sharp tone, fitted to move them; sometimes in a joyful voice, intermingled with songs, which the other ancients repeat in harmony. At the conclusion he shows all these collars as so many deceased persons, formerly of note, who come back to life to urge all those who are present to preserve the country for which they formerly gave their life and shed their blood. All is ended by a feast, and by the offering of many presents, which they make one to another. The ancients of the other families thank him who has spoken, and on the following day they do the same

thing to him, each in their turn. After each family has thus displayed its collars and made its harangue, they all assemble on a day determined, and hanging up the collars in order, each on its own side, they tell one another who are those who have given these collars. " Such a one," they say, " has given this one, or so many thousand beads; another has given these two, these three; another these four collars." Finally they place all these collars together, and put them in the hands of the ancients, who remain their masters. The council is then held to consider how many shall be carried to each nation, to whom they ought to go in embassy, and what affairs should be treated. Some days before the departure of the ambassadors they send a present of porcelain to ask that they would prepare a mat for them to sit and lie upon, and to make known the day of their departure or arrival.

As soon as the news reaches a village, the old men assemble; on their part the young men go to the chase, and everyone contributes the best that he has to regale the ambassadors.

When they have arrived about a musket shot from the palisade, they light a fire in token of peace, in the place where the ancients of the village go to attend them; and after having smoked some time, and received the savage compliments which they make to one another, they lead them to the cabin which is assigned them. They march very gravely and in single file. One of the most notable marches at the head, and he pronounces a grand suite of words which they have received by tradition, and which they repeat after him. The ambassador who is to speak marches last, singing a rather agreeable air, and continues his song until in his cabin, where he also makes five or six turns, singing. Then he sits down the last of all. Then they renew the testimonials of friendship and make presents to dispel fatigue, to wipe away tears, to remove scales from the eyes that they may more easily see each other; finally, to open the throat in order to give a free passage to the voice. These presents are followed by food, which they serve to the ambassadors by way of refreshment. Then they ask them news of their nation, and they reply by recitals which sometimes last all night. The following day they rest, and the third day they make their harangue, show their collars and the subject of their embassy. They answer them the following day, after a public dance which is made around the collars. The whole is terminated by a feast and by the thanks which they mutually make.

The opening ceremonies probably always included the things above mentioned, but otherwise varied much. A single string or belt might include several messages, or be devoted to one. By belts it was usual to dispel the clouds and make the sun appear, to take briers out of the paths, to cleanse blood, to restore the mind,

to bury the hatchet, to kindle the fire and to sweep the hearth. In later times a belt commonly uprooted a tree long enough to bury all troubles under it. With simple addresses all this preliminary wampum was delivered, in order that the council might open fully prepared for harmony of action. These variations are a pleasant subject of study by themselves, and in them will be recognized the truth of Johnson's words in 1771, that the Indians "from their having been next to our settlemts for sevl years, & relying solely on oral Tradition for the support of their Ancient usages, have lost great part of them, and have blended some with Customs amongst ourselves, so as to render it Extremely difficult, if not impossible to Trace their Customs to their origin, or to discover their Explication."

Reference has been made to the exclamations with which wampum was accepted in councils, and many examples might be cited, but one will suffice in which all is described. In the *Collections of the Massachusetts historical society*, 1st ser. v. 7, is *William Marshe's journal*, kept while at a council at Lancaster (Pa.) in 1744. On page 185 he says:

Edmund Jenings, esq. as first commissioner for Maryland, made a speech to the Six Nations, which was interpreted to them by Mr Weiser. Whilst Mr Jenings delivered his speech, he gave the interpreter a string and two belts of wampum, which were by him presented to the sachem *Cannassatecgo;* and the Indians thereupon gave the cry of approbation; by this we were sure the speech was well approved by the Indians. This cry is usually made on presenting wampum to the Indians in a treaty, and is performed thus: The grand chief and speaker amongst them pronounces the word *jo-hah!* with a loud voice, singly; then all the others join in this sound, *woh!* dwelling some little time while upon it, and keeping exact time with each other, and immediately, with a sharp noise and force, utter this sound, *wugh!* This is performed in great order, and with the utmost ceremony and decorum, and with the Indians is like our English huzza!

The sound may still be recognized in Iroquois meetings in New York.

David Zeisberger noted that "the custom of adoption into a family by force prevailed among various tribes. In case of the death of a son or daughter, the parents, with a black belt, hired a captain

to procure a substitute. Collecting his band, this captain went out as for war, and took a prisoner. If he was a white man his head was shaved and painted; in every case the belt was wrapped around his neck, and he was carried off to the bereaved family, which received him with all affection."—*De Schweinitz*, p. 620-21

In Stone's *Life of Joseph Brant*, 1:17, will be found several extracts from Sir William Johnson's diary, relating to a kindred custom. May 22, 1757, he sympathized with a Canajoharie chief, who had lost his mother, and " expected he would remove his concern by going to war, and bringing either a prisoner or a scalp to put in her room, or stead, as is usual among Indians. Upon this Sir William gave him a very fine belt to enforce his request."

A chief brought him four French scalps, May 18, 1758, and said: This scalp (the one with a black belt tied to it painted) I desire may be delivered to my wife's uncle, old *Hickus* of Canajoharie, to replace her mother, who was his sister. This scalp (meaning another upon the same stick, with a bunch of black wampum tied to it) I send to the aforesaid man to replace *Eusenia*, who was *Taraghyorie's* wife. This scalp (meaning a scalp by itself on a stick, with a bunch of black wampum) my cousin, Captain Jacob, gives to replace old King Hendrick of Canajoharie. This scalp (meaning the small one tied round with a bunch of wampum) my said cousin gives to replace *Hickus's* son, who was killed at the battle of the lake under your command.

Small wampum was one decoration of the white dog at the New Year's feast, and sins were confessed on strings of this at that time.

Glass beads

Glass beads were introduced at an early day but had not the same esteem as wampum. They had a moderate use in a public way. In 1633 Le Jeune presented a string of these to three chiefs of different nations in Canada, and glass tubes were among the Huron purchases of that year. In 1635 Brébeuf catechised the Huron children and gave a little glass tube or bead to those who did the best. Bruyas did the same at Oneida in 1670. " Whoever knows how to repeat on Sunday all that is said during the week, has a string of bugle or two little glass beads, or two brass rings." This was a common practice, and the tubes may be several inches long.

When Le Moyne spoke at Onondaga in 1654, two parts of his first word were "100 little tubes or cylinders of red glass, which are the diamonds of the country," and a great collar of porcelain. The 15th present was of these glass tubes. In this he makes these beads equal in value to wampum, but they were rarely used on public occasions. Frontenac, however, gave the Iroquois some packages of glass beads in 1682. They were his fifth word for some Onondaga women. The English also presented the Onondagas with 30 strings of white glass beads in 1687, and 75 similar strings were used in a preceding conference. One Canadian belt, fig. 178, is of glass beads, but this is exceptional, though others might be named. Wampum had an official character belonging to nothing else.

Condolence

The ceremony of condolence, now including the raising of a new chief, is one of the most interesting of surviving Iroquois customs. A similar ceremony was found among most Canadian tribes, involving the idea of a resurrection of the dead chief in the person of the new. In some nations the change was complete. The new chief abandoned his old name and took that of the deceased, assuming his family relations and duties. His old clothes were removed and new garments were given him. Among the Iroquois the change was less complete. The principal chiefs had official names, and the new chief took that of the dead without necessarily losing his personal name, a practice much like our own. At an early day the condolence for a dead Iroquois chief did not usually include the raising of the new one, which made a separate affair. Almost all councils were opened with a general condolence, but there were special ones for this purpose alone. The earliest one of which we have any particular account among the New York Iroquois is that given by Pierron, after the battle between the Mohawks and Mahikans in 1669. It has been mistaken for something like the Huron feast of the dead, of which we have no historic trace in New York. Unfortunately the missionary made needless trouble about what he saw, and withdrew without seeing all. The story will be found in the *Relation* of 1670. Enough will be quoted to show its connec-

tion with the modern condolence. In that the other nations come to comfort the mourning people, and there are reciprocal speeches. The visitors are met outside the town, and some ceremonies take place there. The names of the original chiefs are recited and their virtues praised. Pierron said: "Our sachems having invited me to their ceremonial of the dead, held at *Gandaouagué*, I went to gratify them. The assembly was composed of Onondagas, some Oneidas, and the most eminent of *Agnié*. These were separated from the others according to custom. After the Onondaga had spoken, our *Agnics* discoursed of their fables and superstitions." The Frenchman did not show the politeness of his nation, and the Mohawks were naturally surprised at his interference. One of their chiefs asked him to "withdraw from their company, since they were about to sing according to their custom. It is true that I could understand nothing they sung and would not even countenance it," but he went to the Onondagas and remained awhile with them. "After the ceremony, which lasted for the space of five hours, I went back to the village without waiting for the rest of the ceremony, which belonged to our *Agnies* to terminate."

There are many early references to the minor and greater condolences, and those familiar with the present ceremony will readily see the likeness and difference. No business could be transacted till the dead had been condoled, nor could the mourning nation appear in council till this was done. Just after the French came to Onondaga in 1656 a chief died, and the council could not be held till the town was expiated. One present dried the tears of the Onondagas; another cleansed the council mat. Both French and English soon took a hand in these ceremonies, and there can be little doubt that Johnson modified and enlarged them. The death of two Onondaga sachems had not been condoled in 1697. The following year the Onondagas had not recovered their senses. "The Lieut.-Governor according to ye usual ceremony, gave a bunch of Wampum, condoleing ye Sachems losse and approveing what choice they should make among themselves." At Onondaga in 1701, the Onondagas announced the death of a sachem and offered another with the same name, giving each nation a bunch of wampum. The

Cayugas made a like announcement with similar strings. At Albany in 1737 the four nations present wished public business deferred till Monday, "because they would this day Condole the Death of the two sachems who lately Dyed According to the Antient Custom of their Ancestors and until this was done they were like Children under Age, who cannot Act in publick Affairs."

Wampum was the proper medium in condolences, though other presents were used. Some Cayugas came to Albany in 1697. They said the Senecas had lost several young men in war, and added: "'You know our custome is to condole ye dead by wampom, therefore we desire you give us some for these Beavours;' so laid down ten Beavr skins. The wampum was imediatly given them for the said skins." Two days later some Seneca chiefs came and exchanged beaver skins for condolence wampum. It is indispensable in condolence councils now.

Col. Johnson appreciated the importance of having a part in the condolence. In 1749 he sent Arent Stephens to Onondaga to give "an account of the Peace, which requires a good deal of Ceremony in their way." Then, in Gov. Clinton's name, he was "to condole the death of two old Sachems, one an Onondaga the other an Oneida, and appoint two others of the best, in their room. This ceremony is also attended with a great deal of form; it was always neglected in the late Commissrs time, which gave the French an opportunity of doing it, & appointing such in their room as would do every thing for their interest. Wherefore I shall put a stop to that now." He did so as far as he could, and for the time may have improved on the old ritual. The Onondaga chief, Red Head, thanked him for his interest in 1755, with a string of wampum. "We are much obliged to you for renewing our ancient forms. You have Records of these things, and we thank you for putting us in mind of them by clearing this Council place." He was afterward a prominent figure in many condolences.

The most fully described of these was that of Red Head, or *Kaghs-wugh-ti-o-ni*, at Onondaga in 1756, of which a synopsis may be given here, as it differs much from the present usage, where no belts are used and the addresses are prescribed. June 15 at the

camp at Oneida Sir William and the principal chiefs "of every nation prepared the several speeches of condolence to be made . . . and chose the proper belts for the ceremony." On this occasion the Cayugas, as Younger Brothers, acted for the mourning Onondagas, who were Elder Brothers. June 18 the Cayugas met him and his company a mile from Onondaga Castle, where two hours were spent in arranging the formalities according to the ancient custom. "Then Sir William marched on at the Head of the Sachems singing the condoling song which contains the names, laws & Customs of their renowned ancestors." This was sung mostly by the Oneidas, who were also Younger Brothers. "When they came within sight of the Castle the Head Sachems and Warriors met Sir William, where he was stopped, they having placed themselves in a Half Moon across the Road, sitting in profound silence. There a Halt was made about an hour, during which time the aforesaid Sachems sung the condoling song." This halt is now by a fire on the roadside, at some distance from the council house. "Then Sir William marched on at the Head of the Warriors the Sachems falling into the Rear and continued singing their condoling song." His reception completed the day. The next day "the full council of all the Nations met, with Sir William at their Head, to perform the grand solemnity of Condolence for the Death" of the great Onondaga chief. This was done with 11 belts and three strings of wampum. "The whole Ceremony of Condolence ended" and was very different from the present form. The ancient song is mentioned by others, and included the names. When King Hendrick and others were to be condoled the same year, Johnson could not go, but gave the proper belts. At German Flats in 1770 the speaker of the Six Nations performed the ceremony for the dead, on Johnson's behalf, "and delivered the several belts for the several purposes on such occasions, covering the graves with a black belt, they answering with a *Yo-hah*, customary on condolences." At Sir William's own death a double belt covered his body, and a belt of six rows his grave, but this was a simple sign of mourning.

L. H. Morgan described the mourning council in the *League of the Iroquois*, p. 115-22, but left out several striking features. He

styled it *Hen-nun-do-nuh'-seh*, literally a mourning council, and his description is good as far as it goes. Horatio Hale devoted the *Iroquois book of rites* to this great ceremony, giving some songs in full, but also omitting some peculiar and prominent ceremonies. In a paper on an "Iroquois condoling council," read before the Royal society of Canada in 1895, he gave a full and excellent account. This was published in the transactions for that year. The Onondagas term it *Ho-te-ne-ko-kah-nă-wax*. The writer attended a condolence held by them in 1895. His account will be found in the *Journal of American folk-lore*, 8:313. His description of a Tuscarora condolence appears in 4:39 of the same. These will be summarized, as wampum is not conspicuous throughout.

The Elder Brothers take charge for the Younger, and *vice versa*, and send out invitation strings with tally sticks of days. The condolence is held in the council house of the mourning nation, or one lent to it for the occasion. In 1895 the Onondagas gave the use of theirs to the mourning Oneidas and others, but took principal charge of the ceremonies themselves. In the same way chiefs are often lent to sing the condoling songs in an emergency. The condolers formerly assembled at some distance from the town, but now on some road leading to the council house, till summoned to proceed. Formerly at the wood's edge, but now half way to the council house, a fire is built, and there the mourners wait for their visiting friends, who march on in double file, the leaders singing the condoling song. At the fire the songs are continued, addresses made, and the invitation wampum is returned. In due time the mourners silently lead the way to the council house, the condoling chiefs and friends soon following, singing as before. As the song contains the names and memory of the 52 original chiefs, it is continued for some time in the council house, where the mourners sit at one end, the condolers at the other. Then a cord is stretched across the center of the house, and a curtain hung from side to side. This separates the two brotherhoods. The visitors lay a stick across the benches, and place seven bunches of wampum on this, singing for some time. The curtain is then removed, and a long song follows, the wampum being carried to the mourners at inter-

vals, a bunch at a time, and hung on another stick. The curtain is then again suspended, and the mourners sing till it is once more removed. Then they return the wampum, bunch by bunch, saying, "You said," and repeating the words already given. The new chief is then presented for installation. The wampum has no reference to the ancient song containing the 52 names of the principal chiefs, but to the shorter song here given.

The seven bunches used in the council house are here illustrated by a set lent to the writer by the Rev. Albert Cusick of the Onondaga reservation. He translated the song of the Younger Brothers for Horatio Hale, and this translation is here used, with references to the wampum in due order. Of this part of the ceremony Mr Hale said nothing. It is to be observed that changes are made according to the parties bereaved.

The speaker takes from the stick a bunch of three strings of purple wampum, about 50 beads long, carrying it to the mourners, and makes the following speech:

1 Now—now this day—now I come to your door where you are mourning in great darkness, prostrate with grief. For this reason we have come here to mourn with you. I will enter your door, and come before the ashes, and mourn with you there; and I will speak these words to comfort you.

Now our uncle has passed away, he who used to work for all that they might see the brighter days to come—for the whole body of warriors, and also for the whole body of women, and also the children that were running around, and also for the little ones creeping on the ground, and also those that are tied to the cradle boards; for all these he used to work that they might see the bright days to come. This we say, we three brothers.

Now the ancient lawgivers have declared—our uncles that are gone, and also our Elder Brothers—they have said it is worth 20—it was valued at 20—and this was the price of the one who is dead. And we put our words on it [i. e. the wampum] and they recall his name—the one that is dead. This we say and do, we three brothers.

Now there is another thing we say, we Younger Brothers. He who has worked for us has gone afar off; and he also will in time take with him all these—the whole body of warriors, and also the whole body of women—they will go with him. But it is still harder when the woman shall die, because with her the line is lost. And also the grandchildren and the little ones who are running around—

these he will take away; and also those that are creeping on the ground, and also those that are on the cradle boards; all these he will take away with him.

Now then another thing we will say, we three brothers. Now you must feel for us; for we came here of our own good will—came to your door that we might say this. And we will say that we will try to do you good. When the grave has been made, we will make it still better. We will adorn it and cover it with moss. We will do this, we three brothers.

Fig. 222 represents this speech. Fig. 223 contains some white beads, and is therefore of a more cheerful tone. The bunch is taken from the stick, as before, and borne to the mourners.

2 Now another thing we will say, we Younger Brothers. You are mourning in the deep darkness. I will make the sky clear for you, so that you will not see a cloud. And also I will give the sun to shine upon you, so that you can look upon it peacefully when it goes down. You shall see it when it is going. Yea! the sun shall seem to be hanging just over you, and you shall look upon it peacefully as it goes down.—Now I have hope that you will yet see the pleasant days. This we say and do, we three brothers.

The three strings of fig. 224 are of purple beads, and the speech follows:

3 Now, then, another thing we say, we Younger Brothers. Now we will open your ears and also your throat, for there is something that has been choking you, and we will also give you the water that shall wash down all the troubles in your throat. We shall hope that after this your mind will recover its cheerfulness. This we say and do, we three brothers.

In fig. 225 a few white beads appear. The bunch has its words:

4 Now then there is another thing we say, we Younger Brothers. We will now remake the fire and cause it to burn again. And now you can go out before the people, and go on with your duties and your labors for the people. This we say and do, we three brothers.

Fig. 226 has scattered white beads for the fifth speech.

5 Now also another thing we say, we Younger Brothers. You must converse with your nephews; and, if they say what is good, you must listen to it. Do not cast it aside. And also, if the warriors should say any thing that is good, do not reject it. This we say, we three brothers.

Fig. 227 is of purple beads, relating to the dead chief.

6 Now then another thing we say, we Younger Brothers. If any one should fall—it may be a principal chief will fall and descend into the grave—then the horns shall be left on the grave, and as

soon as possible another shall be put in his place. This we say, we three brothers.

Fig. 228 has some white beads at the end of the strings, as the last speech concludes with a call for the new chief.

7 Now another thing we say, we Younger Brothers. We will gird the belt on you with the pouch, and the next death will receive the pouch, whenever you shall know that there is death among us, when the fire is made and the smoke is rising. This we say and do, we three brothers. Now I have finished. Now show me the man.

After attending a condolence himself, the writer persuaded Mr Cusick to arrange a full set of bunches like those he had seen used, and to give him any needed information. In this and every other effort to put on record the customs of his people, his aid was given at once. Explanations of the song are omitted here, and the bunch to be distributed has been mentioned elsewhere, yet it may be said that being "valued at twenty" refers to the wampum atonement for life, and the horns to official insignia.

In Ely S. Parker's will, dated Aug. 21, 1895, he thus disposed of his wampum received at a condolence: "The wampum in this box is the credentials of my sachemship, and is designated by the Indians as the 'Great horns.' It is the wish of Amanda Poodry of the Tonawanda reservation, and the matron of the Seneca Wolf tribe, that when I die (if I die in New York city) that this wampum be placed upon my coffin until the grave is reached, when it will be taken off and handed to Mrs Harriet Maxwell Converse, who will take the earliest opportunity to restore it to Mrs Amanda Poodry." On the cover of the box was this: "Official wampum. *Donehogawa.* Sacred wampum."

Joseph Brant wrote of a council with western Indians in 1788: "As they had lost three of their chiefs, we went through our ancient custom of condoling with them, by giving about 10,000 wampum, as we could not proceed with our public business till such time as that ceremony was over." This merely expressed sympathy. A letter from Cornplanter to Major Craig is more to the point. It was dated Dec. 3, 1795, a time when some chiefs had resigned and others had been killed. He needed wampum in filling their places, and said, "Now father take Pitty on me & Send me 40 Dollars

worth of Black Wampum & 10 of White & I expect to see it in two Months & an half as I Must Make New Cheifs with it again that time to help Me."—*Penn. mag.* 14:320

Lack of wampum

It sometimes happened that Indians were out of wampum or the supply at a council ran short through unexpected business. This happened to the Five Nations when at Albany in 1714. They gave three sticks and replaced them with belts the following year. At a camp near Tuscarawas (O.) in 1764, large belts were given, but the Delawares gave bundles of 41 and 42 sticks. Colden describes another use of sticks at councils. "The art they have in assisting their memories is this. The sachem who presides has a bundle of sticks prepared for the purpose, and at the close of the message delivered to them, gives a stick to another sachem, charging him with remembrance of it. By this means the orator, after a previous conference with the Indians, is prepared to repeat every part of the message and give it its precise reply. This custom is invariably pursued in all their public treaties."

Beaver skins or other furs were sometimes used in place of belts and strings. At a council between Champlain and the Hurons in 1633 the latter used beavers alone. At another in 1691 the 21 presents of the Five Nations were almost all of beavers and otters. Western and southern nations used pipes and furs. All the colonies could not readily command a wampum supply. In 1677 Maryland wished to send bands of wampum to each of the Five Nations, but, if these could not be had, 20 to 25 guilders worth of strung wampum was to be used. At present one or two beads may be sent with a message, because of their rarity, and sometimes none can be had.

Color of wampum

The color of belts and strings was of importance. White was generally an emblem of something good, and black of affairs of a more serious nature, but this was not invariable. Black wampum, being double the value of the white, was often used to signify affairs of great importance. Several writers of the 18th century

speak of the practice of coloring belts red when the affair concerned war. This was not the only tint employed. In 1757 at a council in Pittsburg a Wyandot "spoke again upon a belt of black and white wampum, the white painted green." Loskiel says, p. 27: Neither the color nor the other qualities of wampum are a matter of indifference, but have an immediate reference to those things which they are meant to confirm. The brown or deep violet, called black by the Indians, always means something of severe or doubtful import, but the white is the color of peace. Thus, if a string or belt of wampum is intended to confirm a warning against evil or an earnest reproof, it is delivered in black. When a nation is called upon to go to war, or war declared against it, the belt is black or marked with red, called by them the color of blood, having in the middle the figure of an hatchet in white wampum.

Heckewelder says, p. 109-10: "White and black wampum are the kinds they use; the former denoting that which is good, as peace, friendship, good will, etc., the latter the reverse; yet occasionally the black also is made use of on peace errands, when the white can not be procured; but previous to its being produced for such purpose, it must be daubed all over with chalk, white clay, or anything which changes the color from black to white. . . Roads from one friendly nation to another are generally marked on the belt by one or two rows of white wampum interwoven in the black, and running through the middle and from end to end. It means that they are on good terms and keep up a friendly intercourse with each other.

A black belt with the mark of a hatchet made on it with red paint is a war belt, which, when sent to a nation together with a twist or roll of tobacco, is an invitation to join in a war." Sometimes the clay may have signified grief. The most remarkable departure from this rule was in 1756 when the French sent a string of wampum to condole the losses of the Five Nations and a white belt for the death of some of their sachems. Another instance was in 1699, when at Albany "the death of *Aquendero* chief Sachim of Onnondages son was condoled according to their custome by giving of some white Wampum to the Sachems which was kindly accepted."

Some attention to color is seen in Sir William Johnson's address to the warriors at Onondaga in 1756. He said: "With these

Strings of Wampum I paint you as becomes Warriors." He gave five large black strings. "With these Strings of White Wampum I feather your heads as is customary among you when engaged in war." Four strings of white wampum. Other instances might be cited.

There were notable occasions when Johnson departed from the significance of color, and he seems to have been partial to the precious black wampum. It did not mean peace but something of high importance. So he gave a peace belt of black wampum to a Chippewa chief at Niagara in 1759, and another black belt inviting him to trade at Niagara and Oswego. No intimation is there of a change of color. A war belt which he gave at Canajoharie the same year was painted.

Tribute

However strong the upper Iroquois may have been, the Mohawks were in a feeble condition till the arrival of the Dutch and the opening of trade. They at once bought guns and used them well. In an account of New Netherlands, written in 1646, we are told that "400 armed men knew how to make use of this advantage, especially against their enemies dwelling along the river of Canada, against whom they have now achieved many profitable forays, where before they had but little advantage; this caused them also to be respected by the surrounding Indians even as far as the seacoast, who must generally pay them tribute, whereas, on the contrary, they were formerly obliged to contribute to these." In 1643 a party of *Mahikans* (Mohawks?) went to collect tribute of the *Weckquaesgeeks* in Westchester county, and of the Tappans west of the Hudson river. They were armed with guns. Not much later some Mohawks took Jogues with them when going to receive tribute from subject tribes. De Witt Clinton notes that the Montauks paid tribute to the New England colonies by 1646, while the river and shore Indians soon "became subject to the Iroquois and paid a tribute in shells and wampum." Colden records this also. When De Courcelles invaded the Mohawk country in 1666, he learned that they and the Oneidas had gone to war against those called wampum-makers.

Others also became tributary. In 1707 the Nanticokes said there had been peace between them and the Five Nations for 27 years, and that they were tributary. That year they carried 20 wampum belts as tribute to Onondaga. The year before they showed a white belt with three black hands on it, which the Onondagas gave them when they became tributary. In 1712 it is said that the Delawares had long before been tributary to the Iroquois. On their way to Onondaga they called on the governor of Pennsylvania and showed what they bore. They "laid upon the floor 32 belts of wampum of various figures." They made a mental reservation. Of the belts "these last 24 were all sent by the women, the Indians reckoning the paying of tribute becoming none but women and children." In this light the Five Nations looked on them all. The Iroquois never considered their own gifts of wampum in the light of tribute. It was an honorable act, having official character.

In the *Relation* of 1660, p. 6, the varying fortunes of the Mohawks are described. They had "been so many times at the top and bottom of the wheel in less than 60 years, that we find in histories few examples of like revolutions. As they are insolent by nature and very belligerent, they have had to do with all their neighbors. . . We can not go very deep into the investigation of what has passed among them, since they have no other libraries than the memory of the old men, and perhaps we would find nothing there which would deserve light. What we learn then from these living books is that toward the end of the last century the *Agnieronnons* (Mohawks) had been brought so low by the Algonquins that there appeared scarcely any of them on the earth; that yet this few which remained, as a generous germ had so sprouted in a few years that it had reduced the Algonquins in turn to its own condition. But this state did not continue long, for the *Andastoeghronnons* made such good war upon them for 10 years that they were overwhelmed the second time, and the nation was almost extinct, at least so humiliated that the name of Algonquin alone made them shudder, and his shadow seemed to pursue them even into their fireplaces.

It was at this time that the Dutch were taking possession of these coasts, and that they took a fancy to the beaver of these people

some thirty years ago; and in order to gain them the more they furnished them with fire-arms, with which it was easy for them to vanquish their vanquishers, whom they put to flight, and whom they filled with terror at the mere sound of their guns."

This is not in accord with the popular opinion that the Iroquois ruled over the shore Indians in Hiawatha's time, and received tribute from them, but it is in exact agreement with known facts and shows why the Iroquois knew so little of marine shells before the Dutch came. Powerful enemies shut them off from the ocean. In 1630 the Mohawks were almost annihilated; before 1600 they were at a low ebb, and obliged to find strength in the Iroquois league. They could not conquer the wampum-makers then; they had little with which to buy, but time, union and opportunity brought a great change.

Atonement

On the theory that putting a murderer to death would not restore life to the victim or help his friends, the Indians often received a blood atonement, which, in their words, "covered the grave." Among the Hurons this was not always easily made. In the *Relation* for 1636 we are told that they sometimes punished the murderer in a peculiar way, after receiving some atonement in presents. These were not then a full expiation. The corpse was stretched on poles, under which the manslayer was placed. A dish of food before him was soon filled with the decaying matter from above, and to secure its removal he must make a present of 700 wampum beads, called *hassaendista.* He was kept there at the pleasure of the relatives, and when released he made another rich present, called *akhiataendista.* A Frenchman was killed by some Hurons in 1648, and the Jesuits demanded presents by a number of sticks tied together. These were given. For a Huron killed by a Huron they commonly made 30 presents. For a woman 40, because she could not so well defend herself, and because they thought women's lives worth more. For a stranger they asked still more, because frequent deaths of these might hinder trade or cause war.—*Relation,* 1648, p. 80-81

L. H. Morgan said that among the Iroquois "six strings was the value of a life, or the quantity sent in condonation, for the wampum was rather sent as a regretful confession of the crime, with a petition for forgiveness, than as the actual price of blood." Loskiel

says: "For the murder of a man 100 yards of wampum, and for that of a woman 200 yards must be paid by the murderer."

The classification of atoning gifts among the Hurons in the *Relation* of 1636, p. 119, is of interest. They were of wampum when it could be had, but other things were used. The presents were of two kinds. The first were to make peace, and to take away the desire for vengeance. "The others are put upon a pole which is extended above the head of the dead, and they call these *Andaerraehaan*, that is to say, those which are put on the pole. But now each of these presents has its particular name. Here are those of the first nine, which are the most considerable and sometimes each of a thousand grains of porcelain." The account may be summarized.

The chief who performs the ceremony speaks in a loud voice in the name of the culprit, and takes the first present in his hand as though it were an axe in the fatal wound. He says he withdraws the axe from this and causes it to fall from the hands of the avenger. This is called *Condayee onsa hachoutawas*. This is followed by the second, *Condayee oscotaweanon*, which dries up the blood. These two express regret for the murder and a wish to restore life if this were possible. The third present refers to the injury done to the nation. The speaker uses similar words, saying, *Condayee onsa hondechari*, which restores the land to its former condition. The fourth, *Condayee onsa hondwaronti etotonhouentsiai*, puts a stone over the cleft in the earth made by this murder. These affect the public and are of great importance. The fifth, *Condayee onsa hannonkiai*, levels the roads and removes the briers, so that there may be pleasant and safe intercourse. The next four are addressed directly to the relatives to console them and dry their tears. *Condayee onsa hoheronti*, he says to the father or mother, as though he would give them something to smoke, thus appeasing every passion. A seventh present restores the spirits of the mourners, and is called *Condayee onsa hondionroenkhra*. *Condayee onsa aweannoncwa d'ocweton* gives a healing beverage to the mother, and the ninth, *Condayee onsa hohiendaen*, spreads a mat for her repose during her mourning.

These were the principal presents. The others represented the

things useful to the deceased during life. They are his robe, collar, canoe, paddle, nets, bow and arrows, and many other things. With these gifts thus properly presented the relatives were usually satisfied.

There are some interesting notes on presents in general and the atonement in particular in the *Relation* of 1642, p. 53.

The presents among the peoples are all the affairs of the country: they dry the tears, they appease anger, they open the gate of the country to strangers, they deliver prisoners, they revive the dead. Nothing is said, as it were, and nothing answered but by presents; it is on this account that in harangues the present passes for a word. They make presents to animate men to war, to invite peace, to induce a family or nation to come and take a place and dwell near you, to satisfy or pay those who have received any harm or any wound, specially if blood has been shed. The presents which they make for the death of a man who has been murdered are in great number; and observe, if you please, that it is not usually the assassin who makes these but the relatives, the village or the nation, according to the quality or condition of him who has been put to death. Nor yet think that this procedure gives some liberty to mutinous spirits to make a bad stroke. Not at all. The trouble into which a murderer throws all the public powerfully restrains. Besides which, if he meets the relatives of the deceased before what he has done is satisfied, he is put to death in the field without other form of justice.

In this way the tribe was interested in the good conduct of every member, and this responsibility had a good effect.

There is an allusion to this atonement in the condoling song which is sung in presenting the wampum after the curtain is removed. "Now the ancient lawgivers have declared—our uncles that are gone, and also our Elder Brothers—they have said it is worth 20—it was valued at 20—and this was the price of the one who is dead. And we put our words on it, and they recall his name —the one that is dead. This we say and do, we three brothers."

That is, 20 strings atoned for a life, as Onondagas tell the writer. They put their comforting words on this, recalling the name of the dead and raising him to life in his successor. Hale said: "The interpreters explained that by 20 was understood the whole of their wampum, which constituted all their treasure. A human life was

worth the whole of this, and they freely gave it, merely to recall the memory of the chief who was gone."—*Hale*, p. 167

Food and burial

Shellfish formed a large part of the food of the aborigines on the seacoast. They ate many on the spot, and dried others for winter consumption. In this way were formed the numerous shell beds near the shore, usually made up of hard clam and oyster shells, but sometimes of the scallop. On Iroquois sites in the interior are often scattered those of the fresh-water clam. There are rare instances there of beds of these of an earlier date. Near the sea the dead were sometimes buried in shell heaps, and in a few cases dogs were carefully interred. For burial purposes the shells were neatly arranged. Careful observers now give a much lower antiquity to these shell heaps than was formerly claimed, and some are evidently of very recent date. As food our water mollusks have probably been long in use here. As ornaments their shells may have been sparingly used in New York four centuries ago. There is little proof of so long a use as this, but it may well be supposed that much has perished. In two or three instances a higher antiquity may be allowed, for wandering hunters may have brought some here. It is not a question of the presence of man in New York, but simply of his use of one common material.

After these pages were in type the writer examined a fine recent belt, 47 inches long and six broad, with 18 rows of beads, mostly white. It has three triple diagonal bands of black beads, and letters and figures in black at one end. If this was considered the bottom there would be 1800, and M C beneath. It probably should be reversed and would then be W C 1800. Captain William Claus had then been recently appointed deputy general superintendent of Indian affairs in Canada, and it seems a belt used by him. It resembles the Simcoe belt in material and construction, and has buckskin thongs. In the terminal fringes are a few blue and white beads, as large as marbles. This is a novel feature.

EXPLANATION OF PLATES

Page numbers refer to fuller descriptions in bulletin.

Plate 1

Plate 2

Plate 3

All reduced

Plate 4

Plate 5

Plate 6

Plate 9

Plate 12

Plate 13

Plate 14

The belts on this plate were photographed by W. M. Beauchamp at a council at *Ohswelcen*, Canada, in 1899:

Plate 21

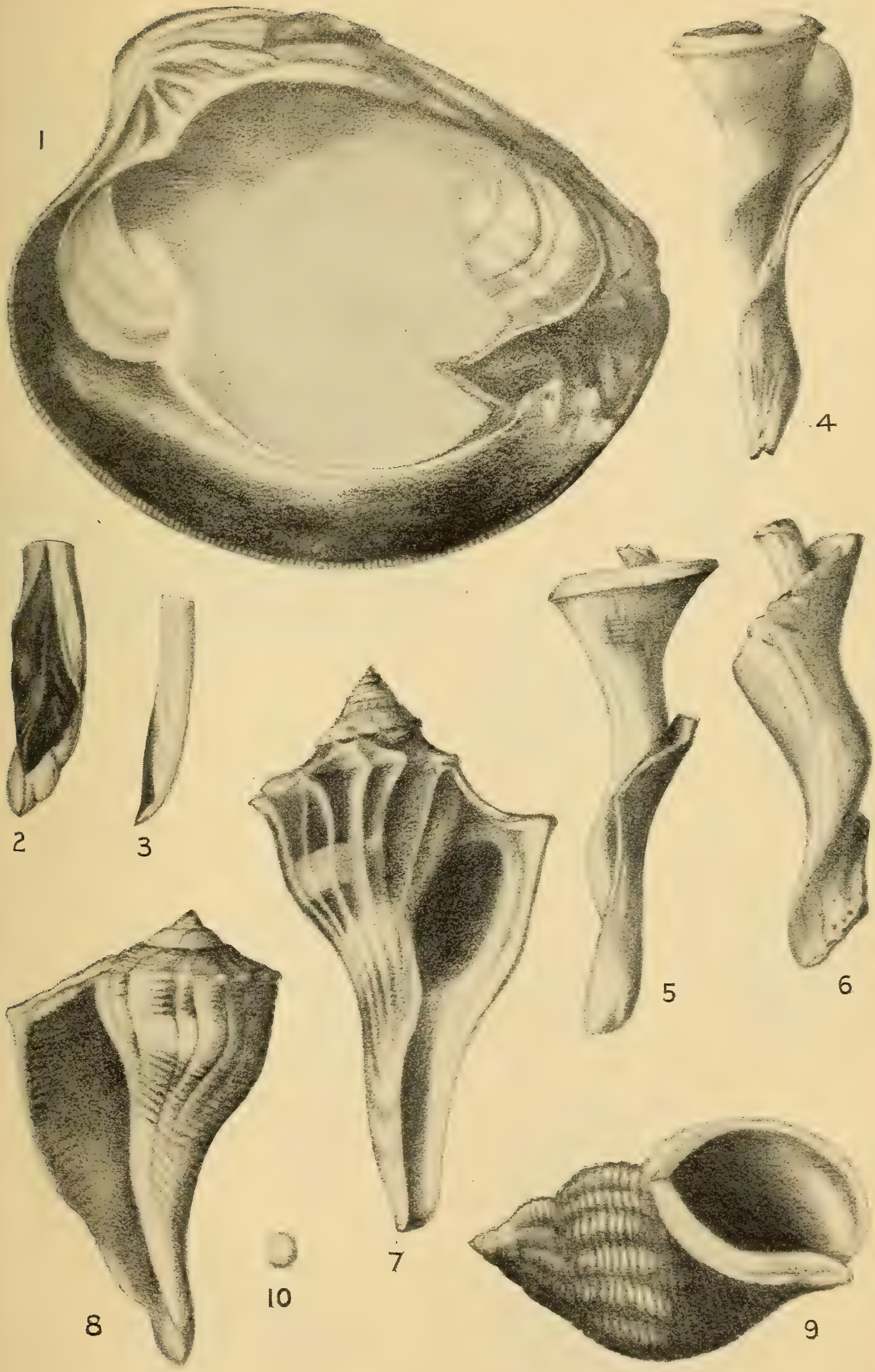
Plate 22

Plate 23

Plate 24

Plate 25

Plate 1



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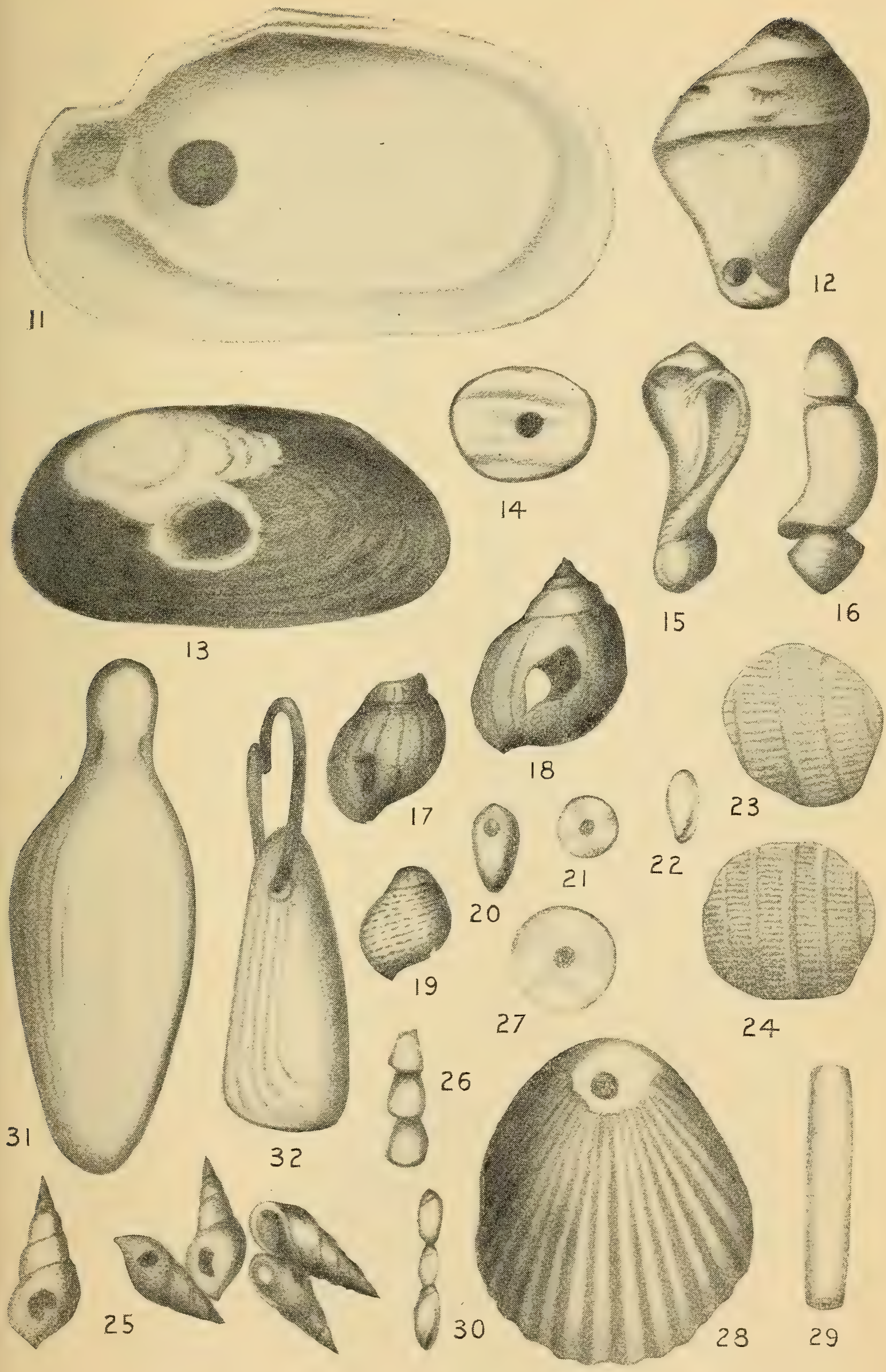

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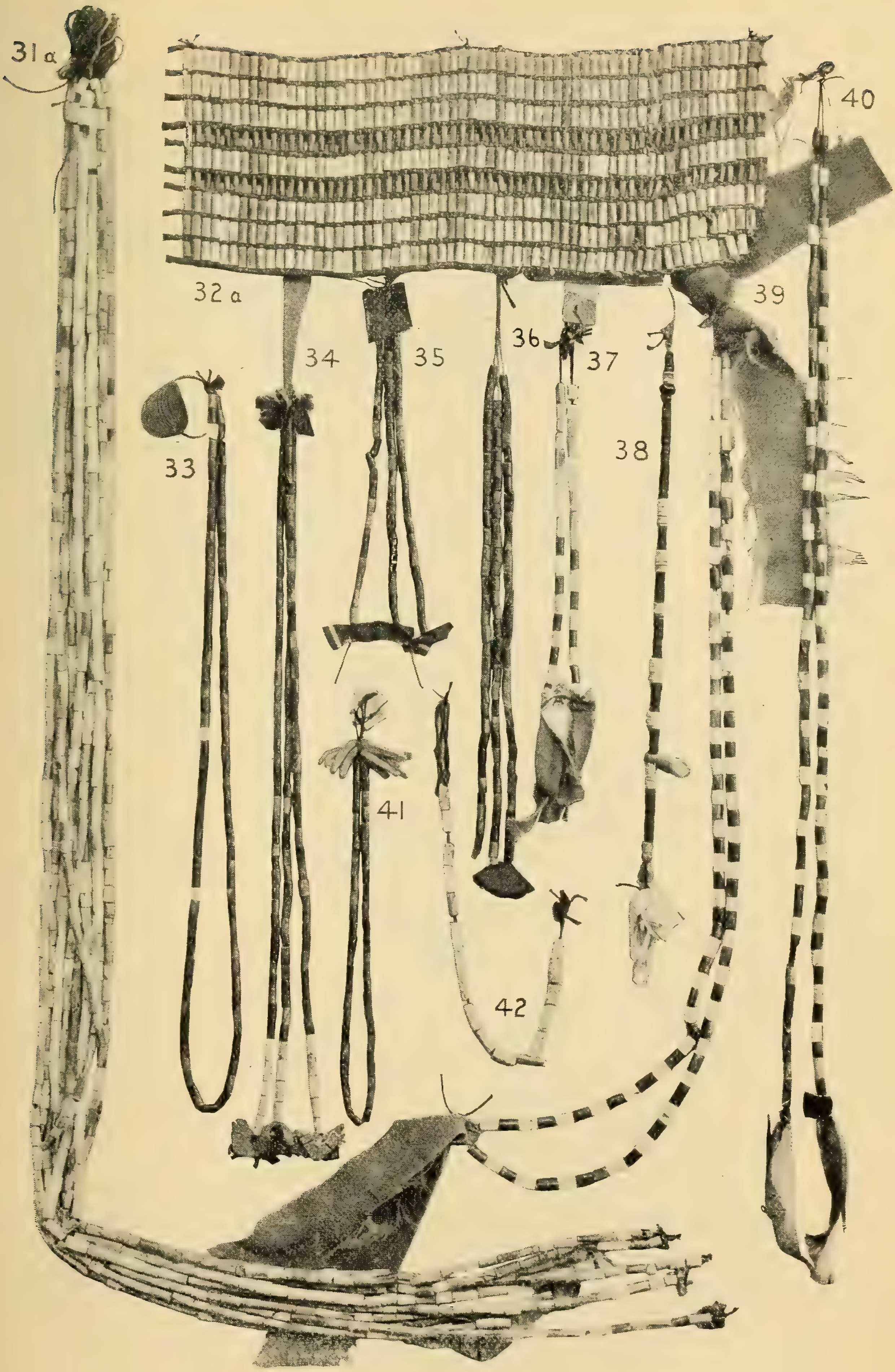

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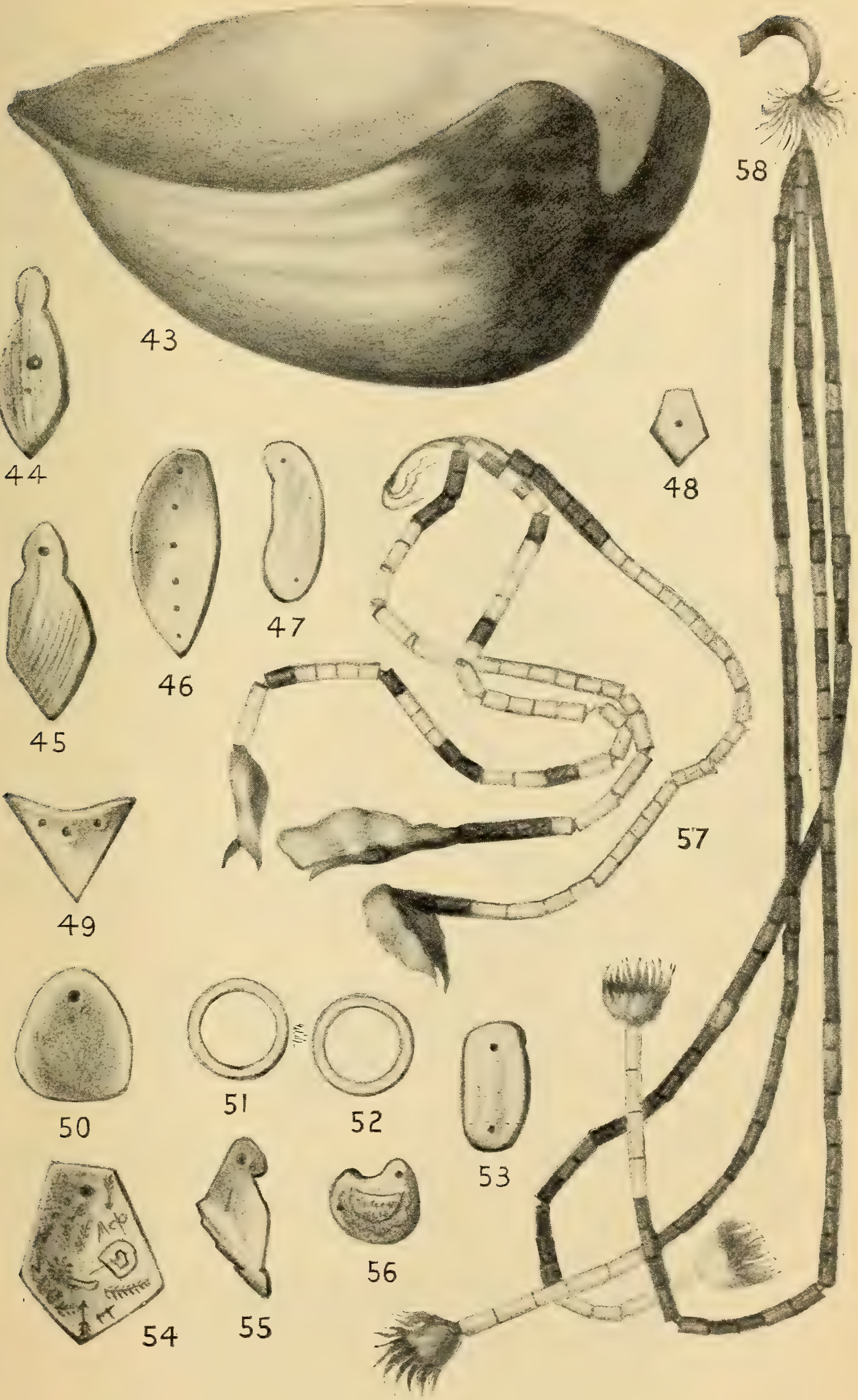

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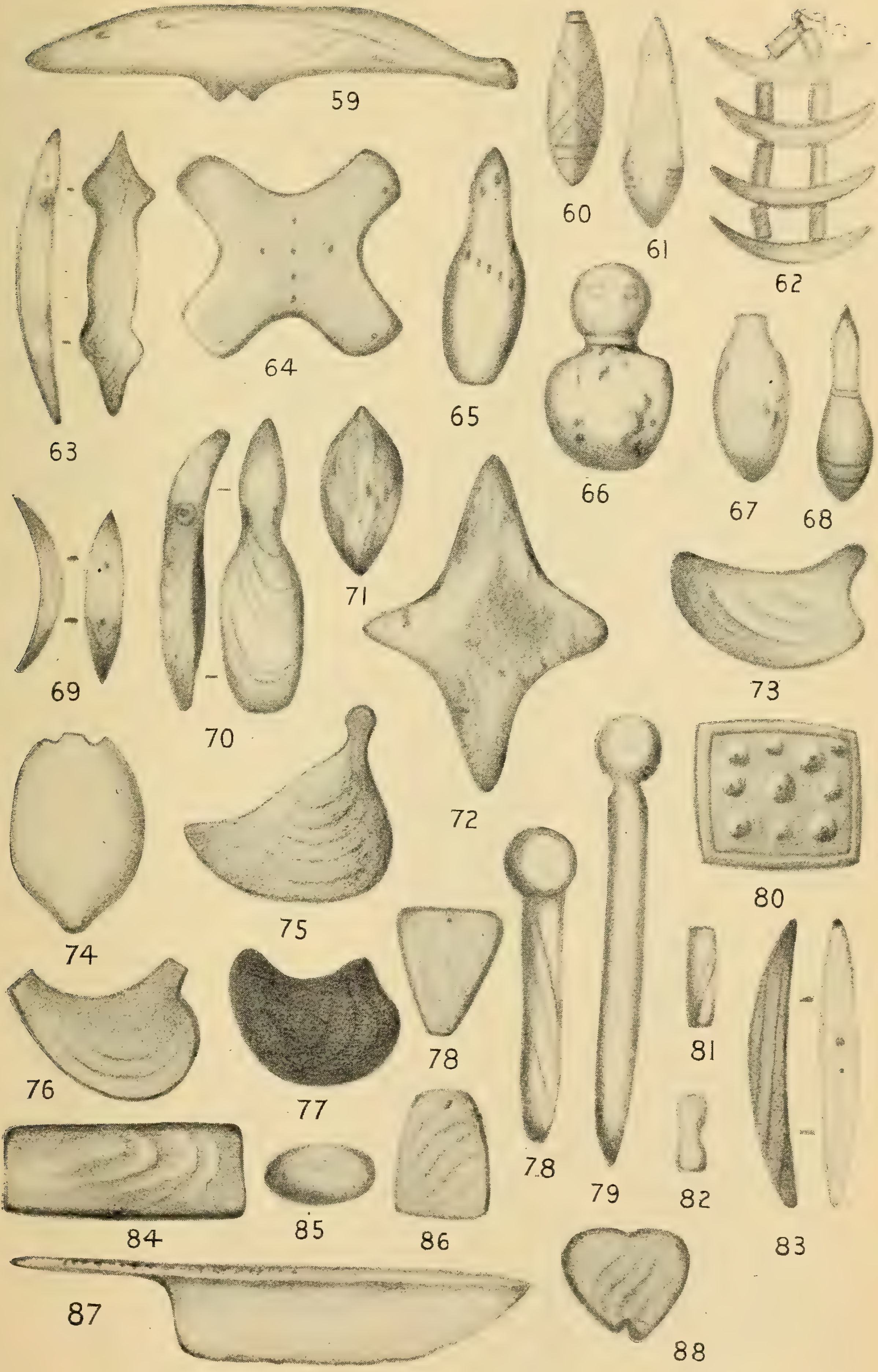
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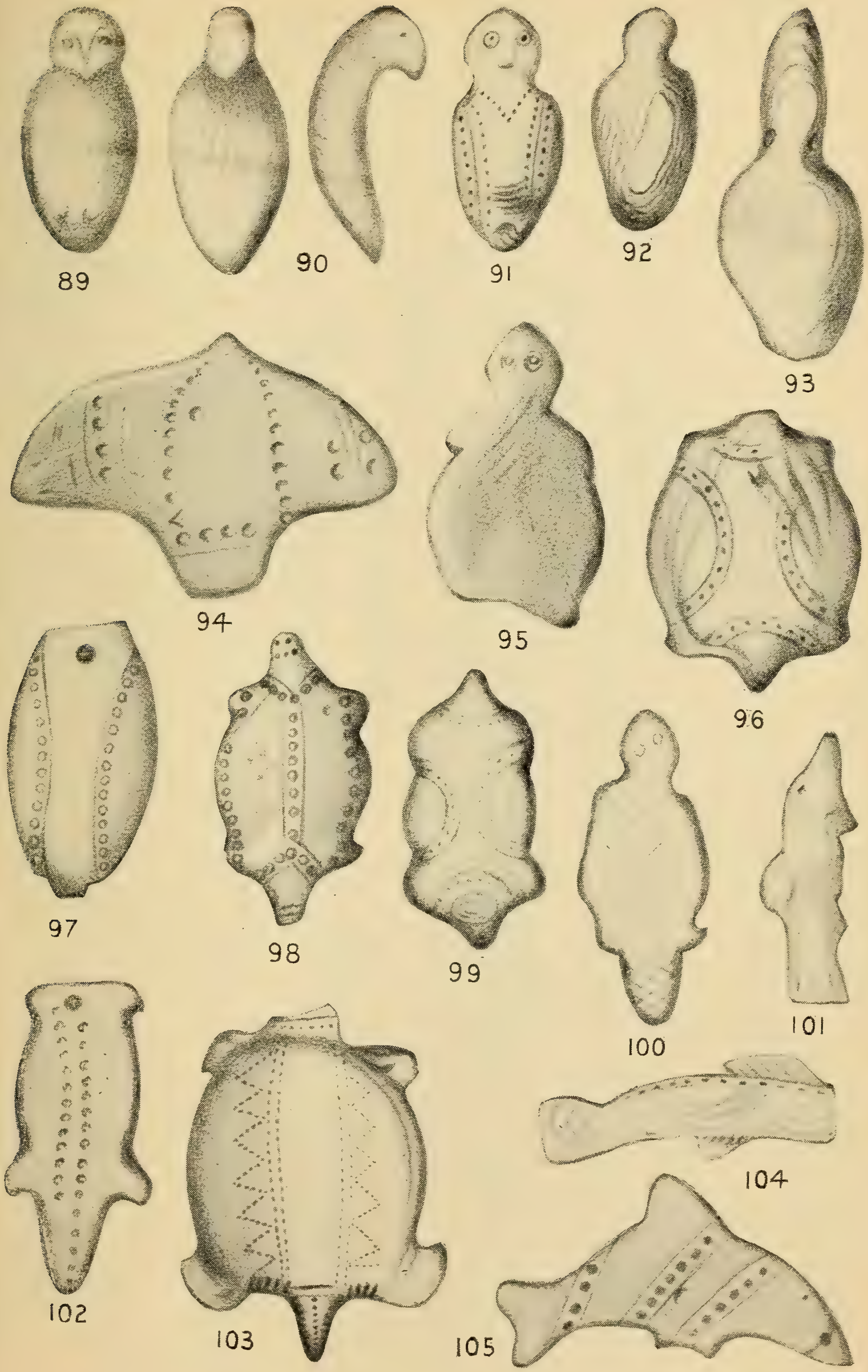

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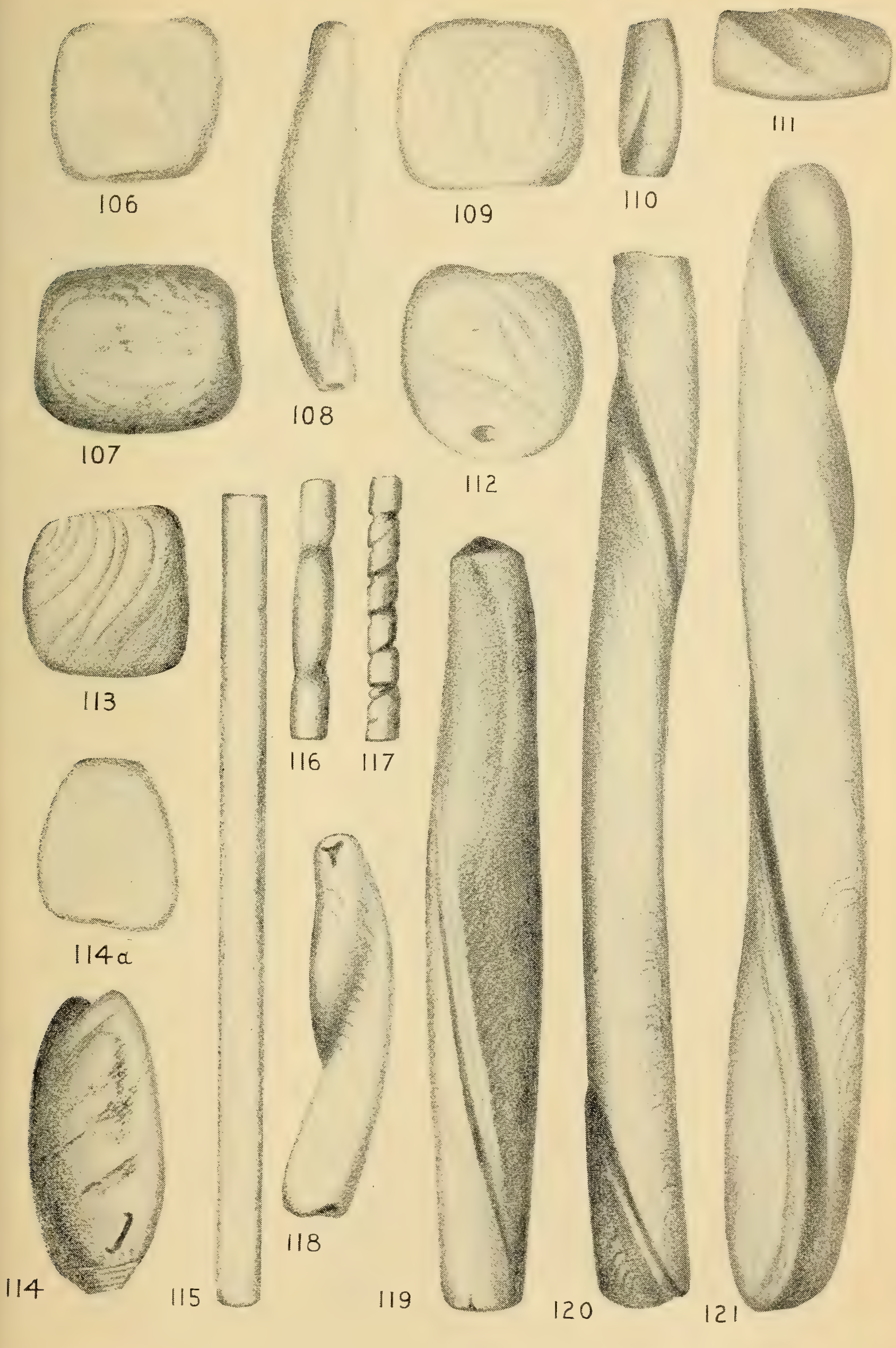
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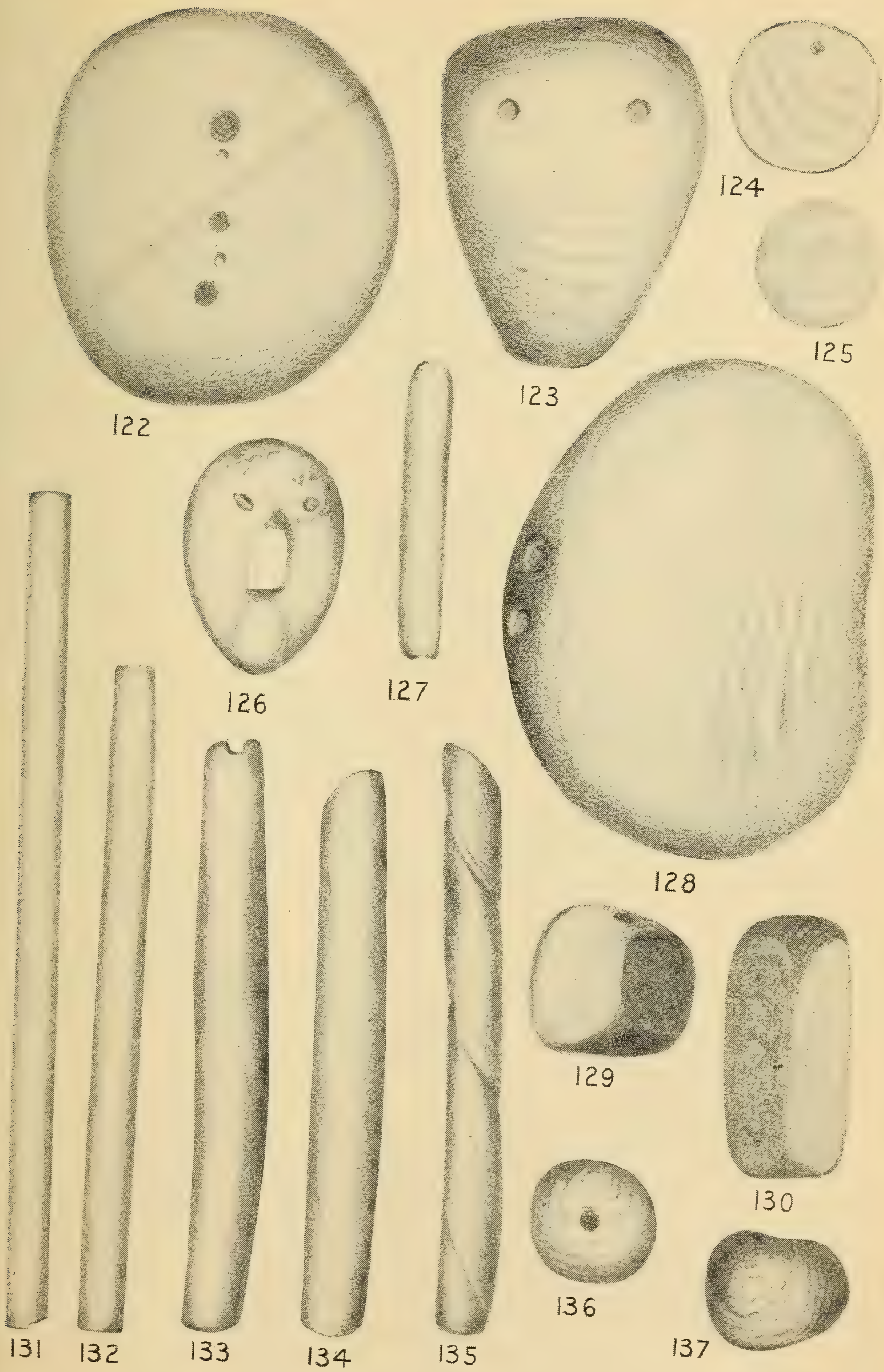

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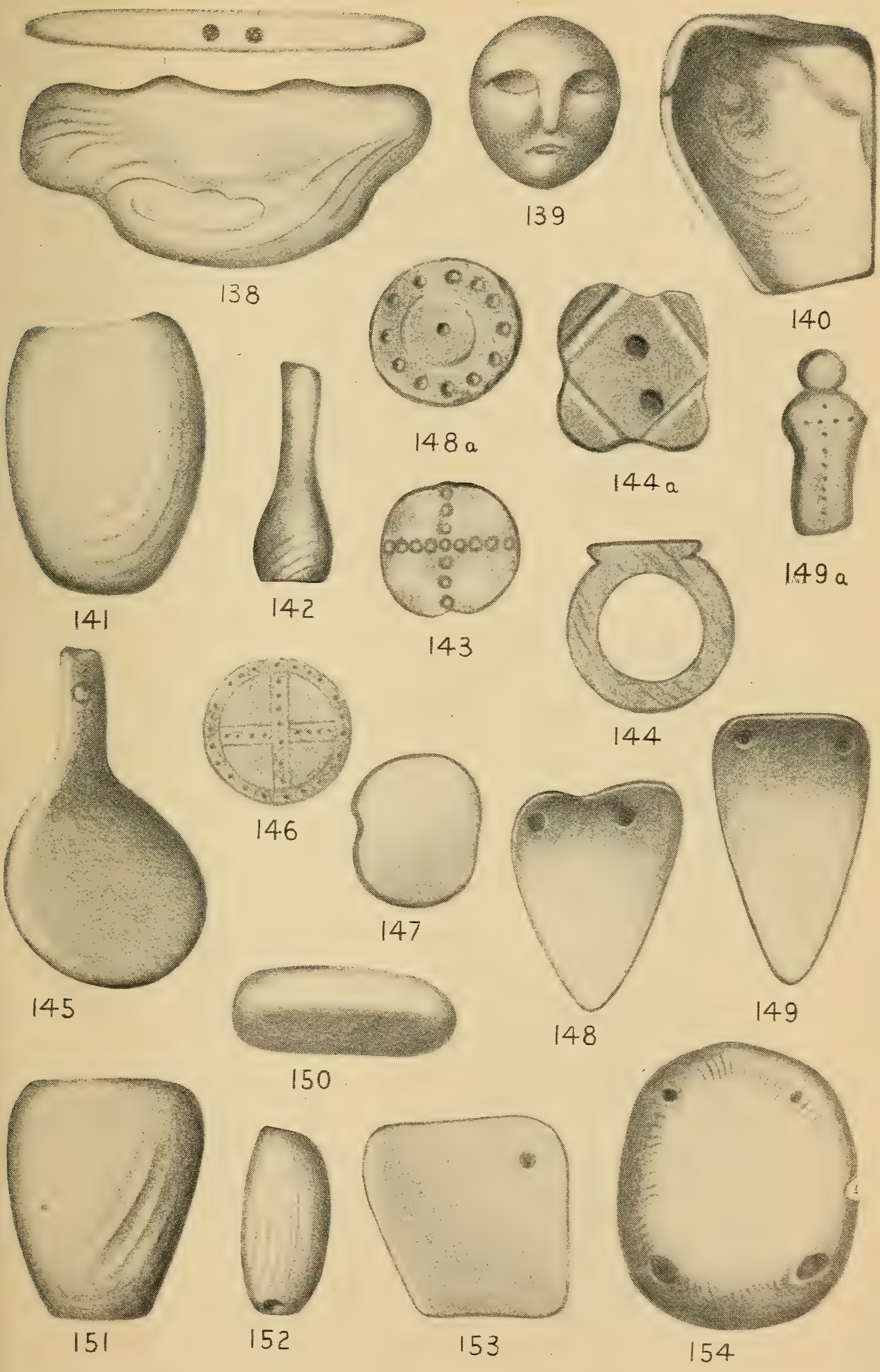
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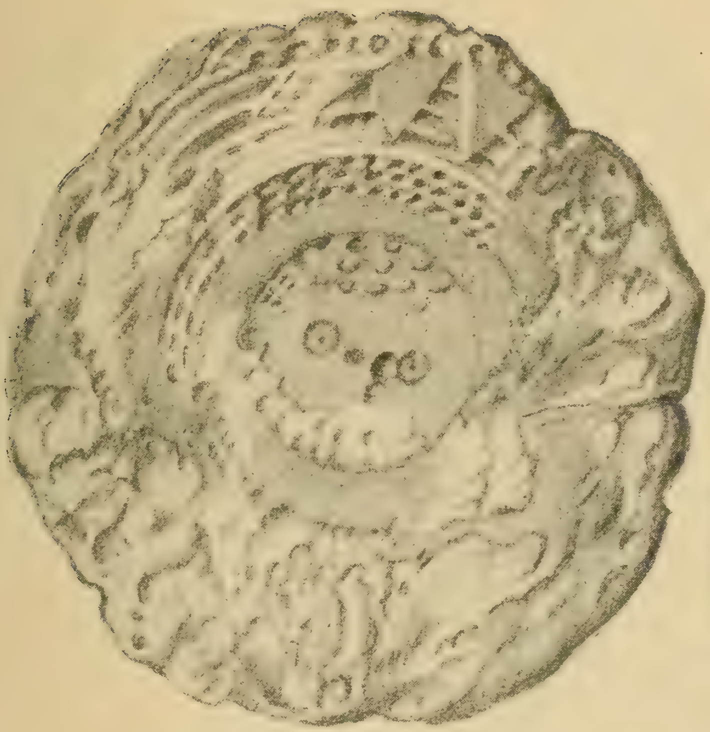

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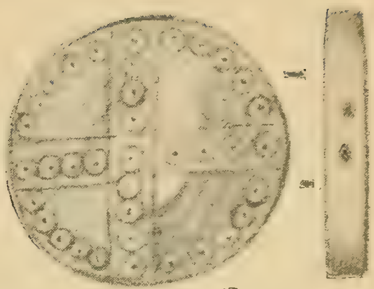

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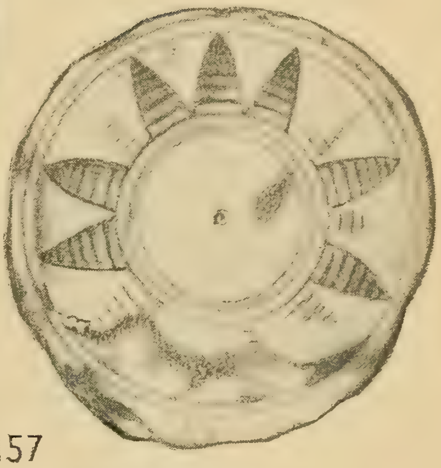

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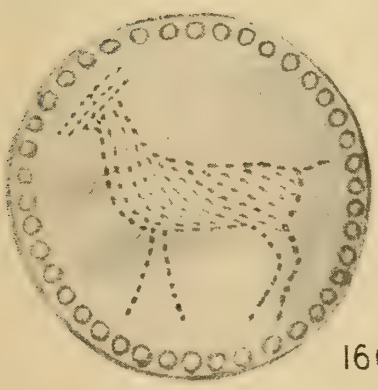

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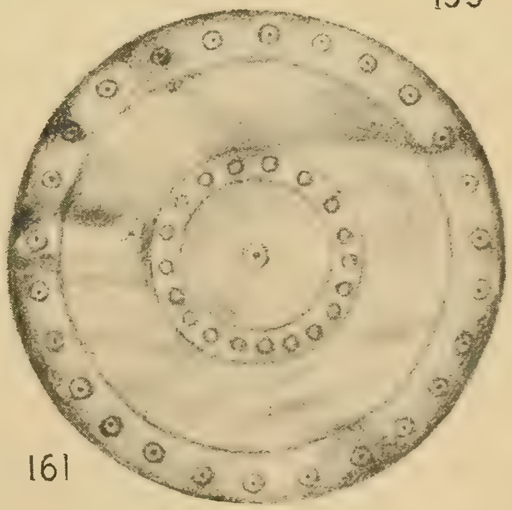

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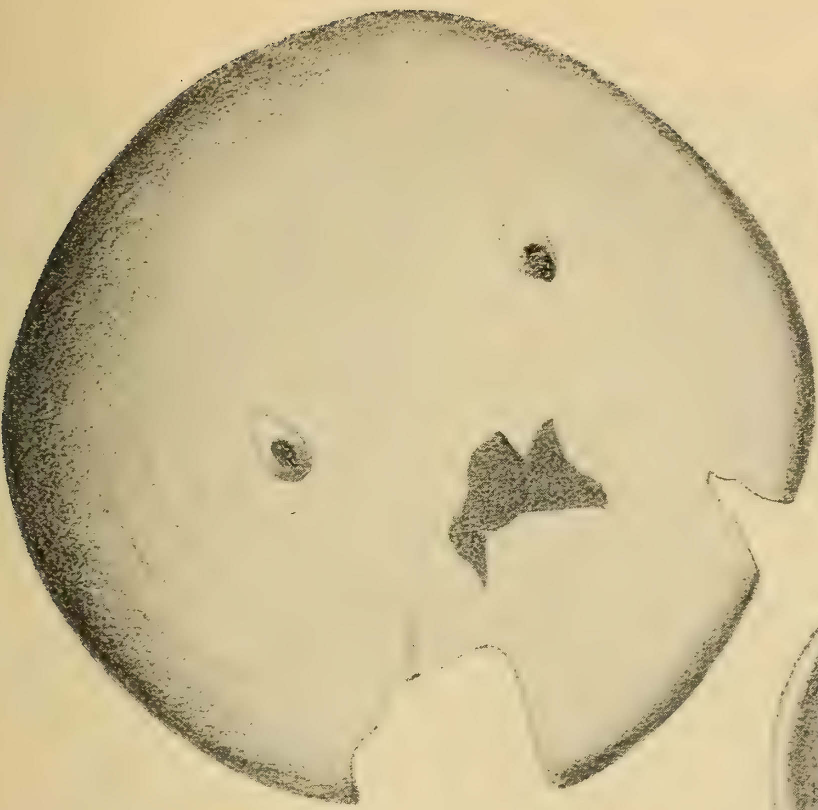

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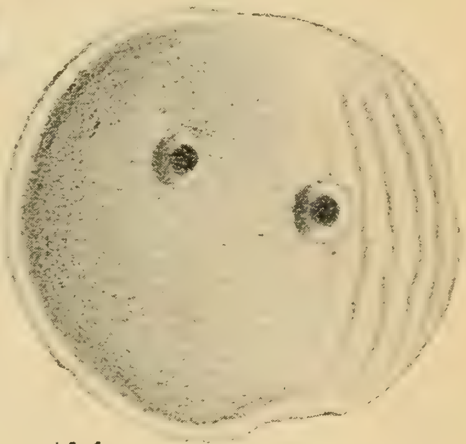

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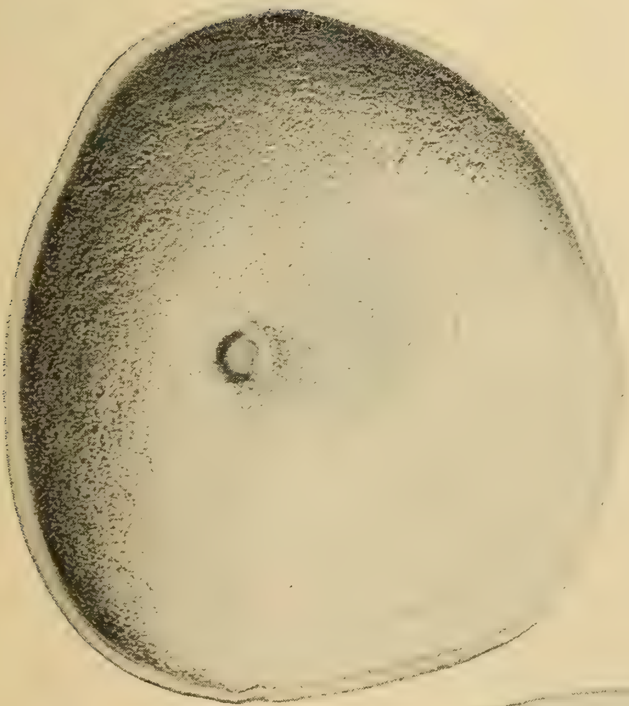

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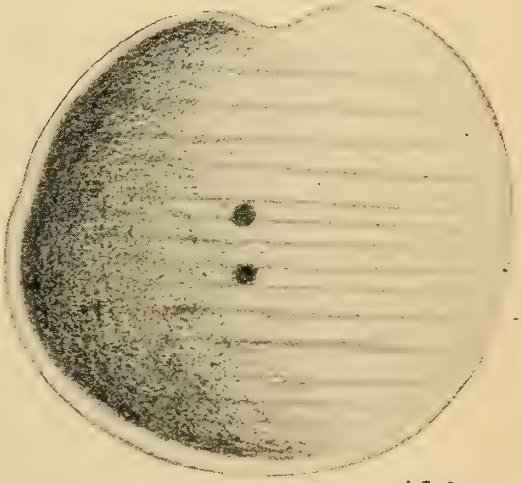

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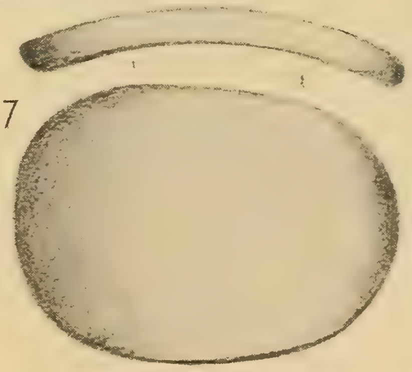

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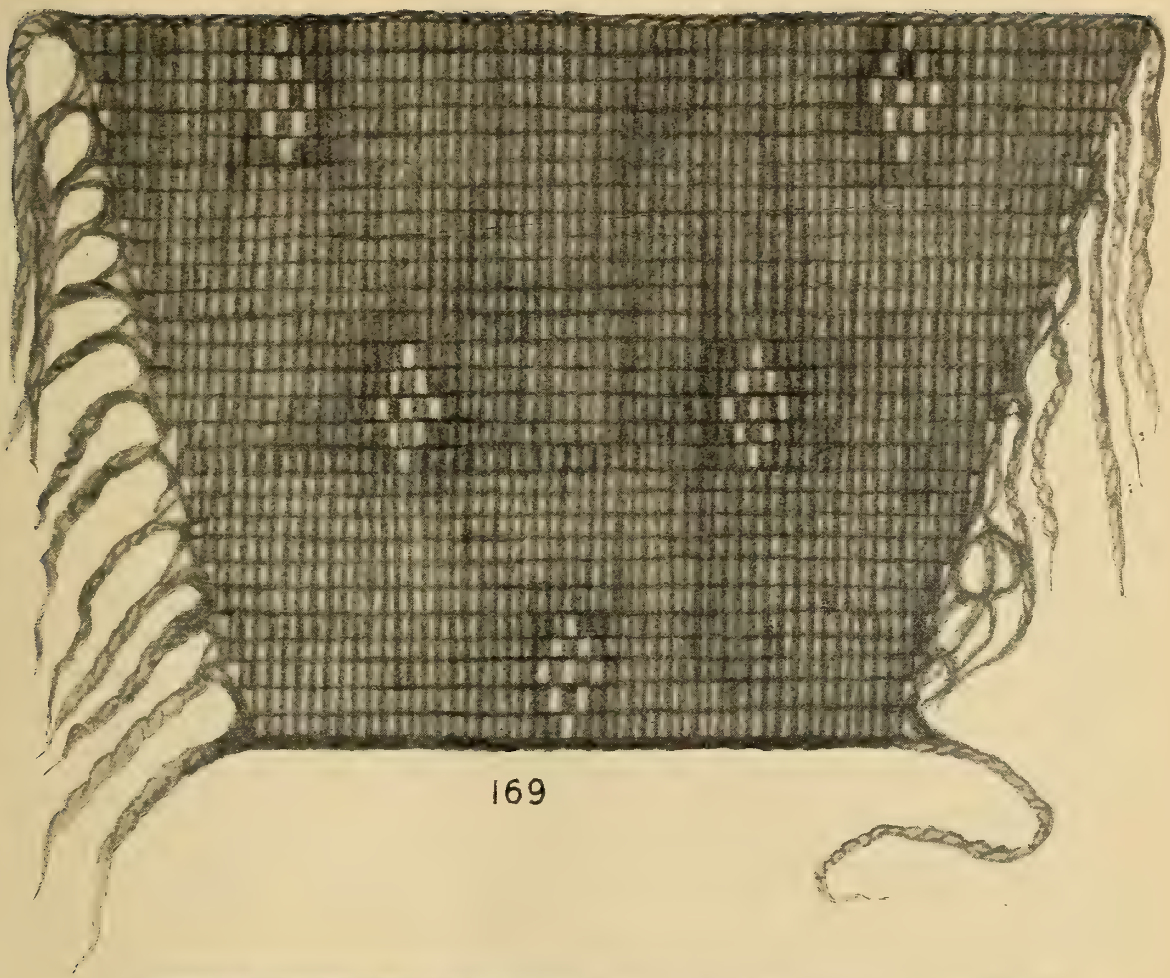

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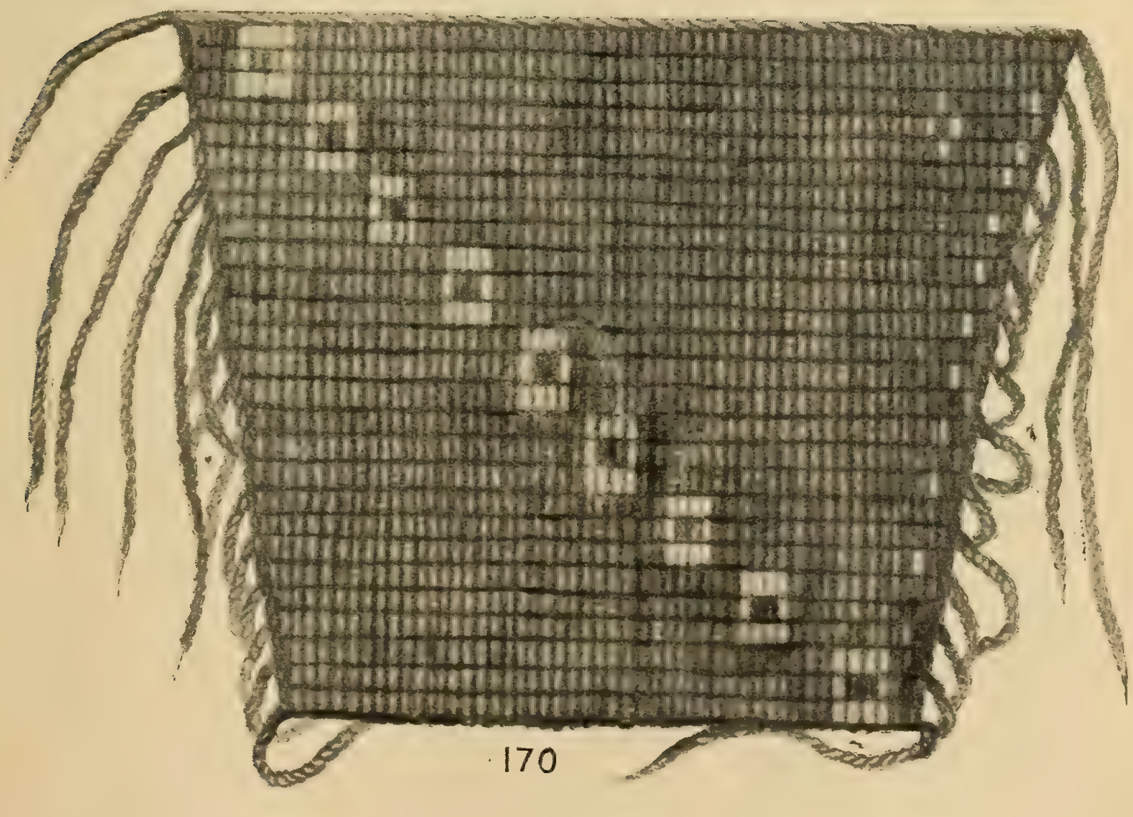

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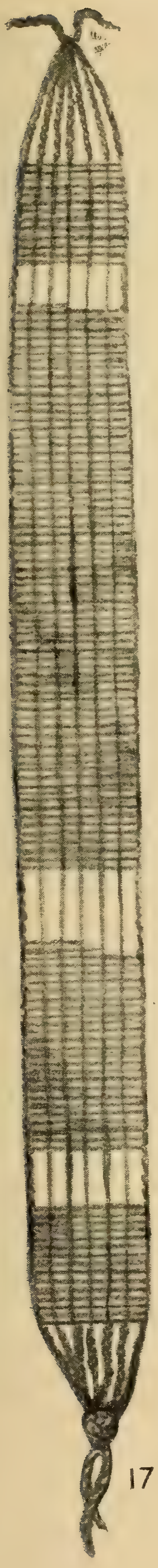

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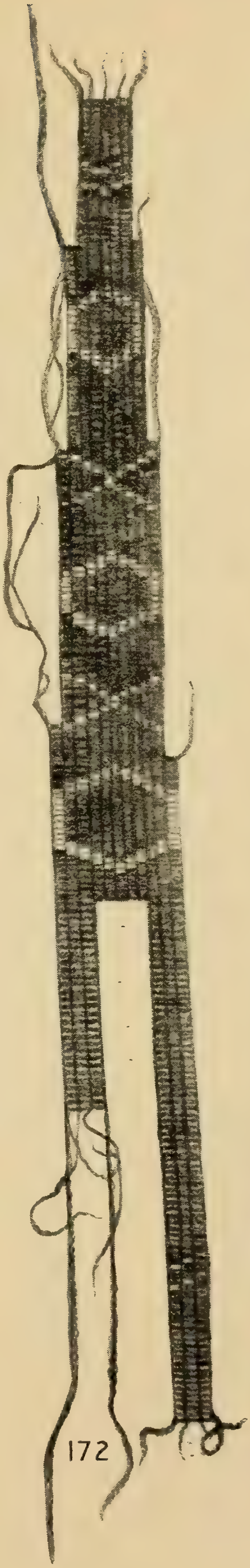

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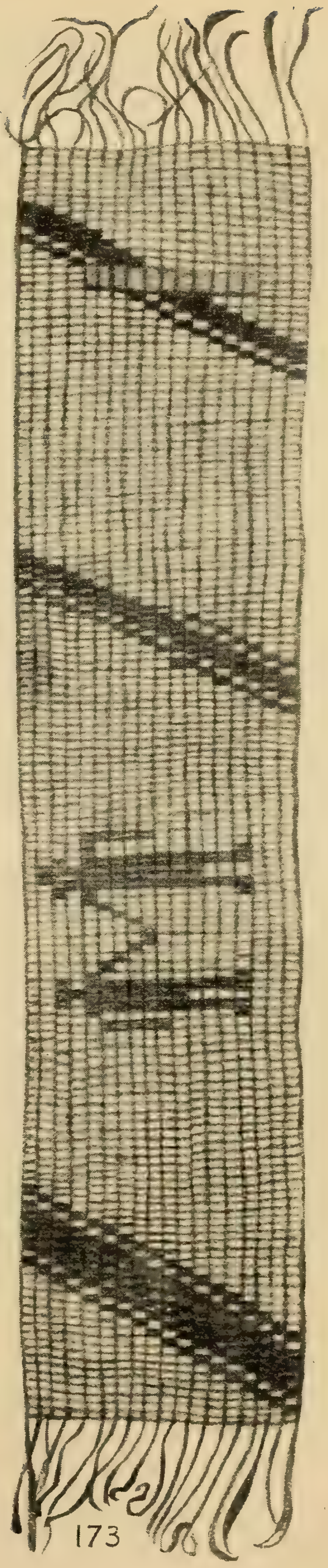

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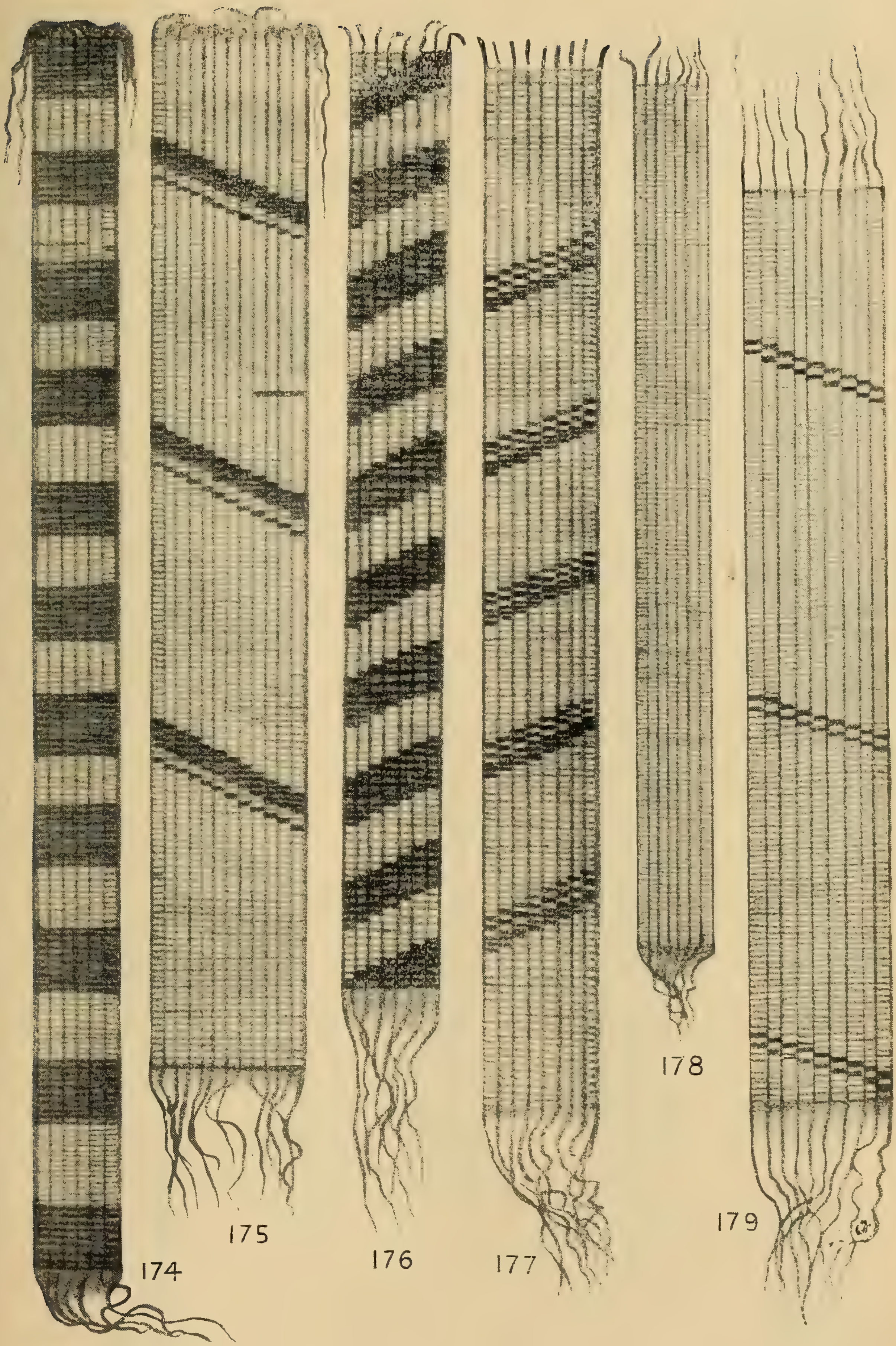

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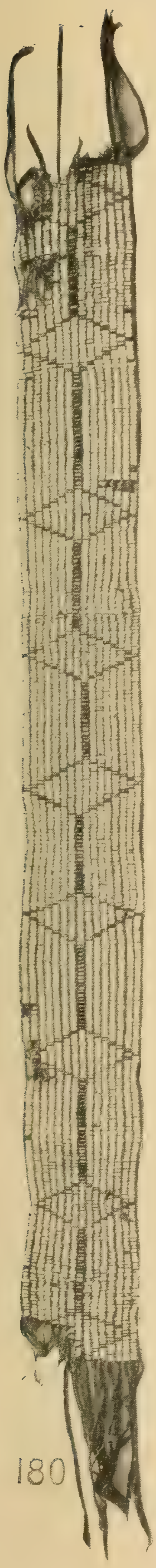

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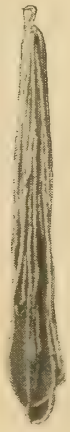

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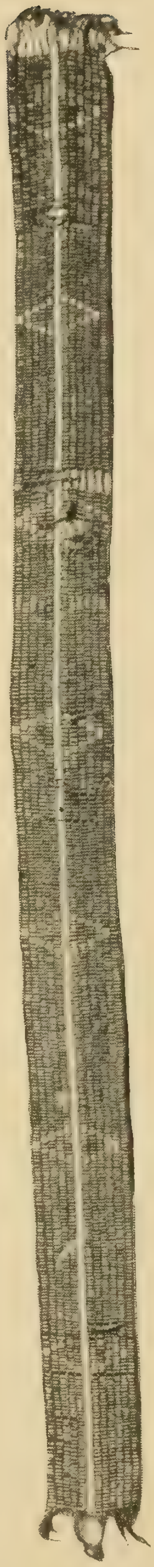

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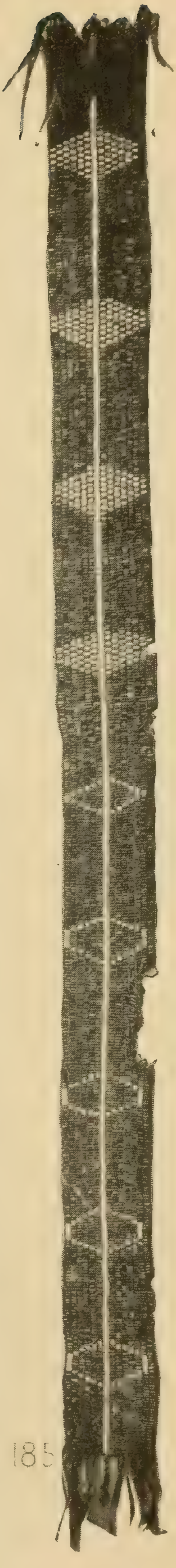

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Plate 16


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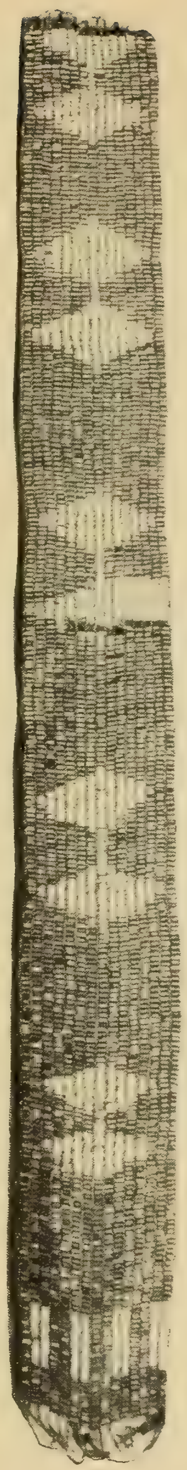
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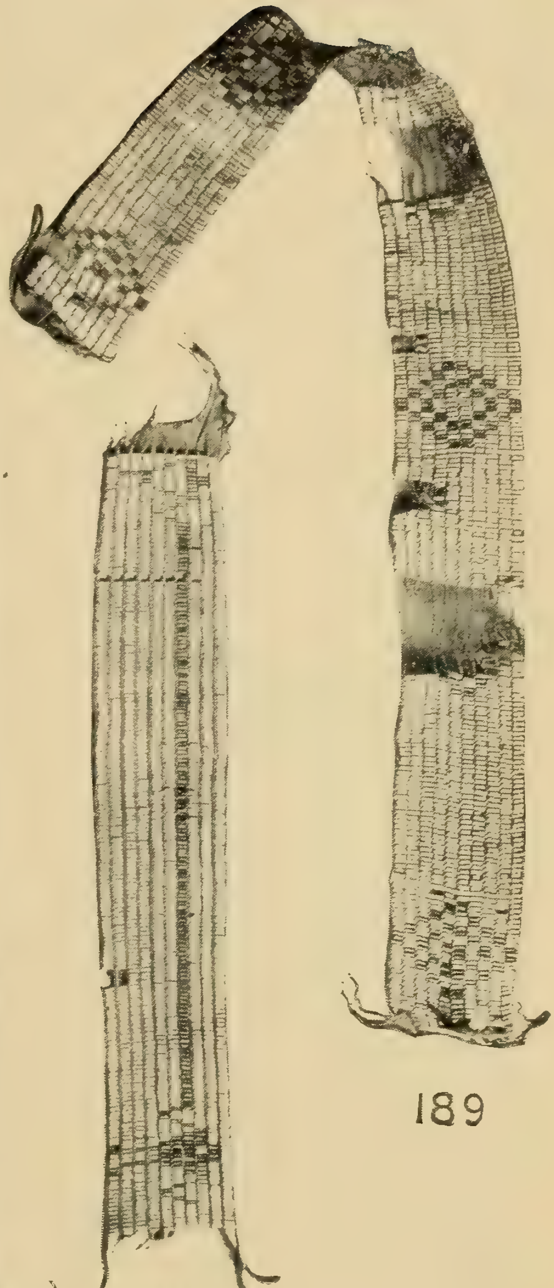
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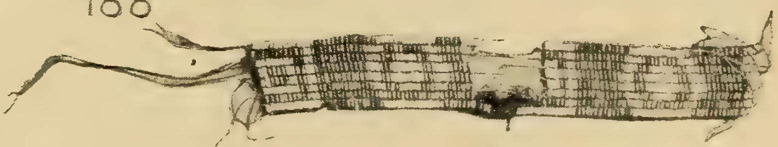
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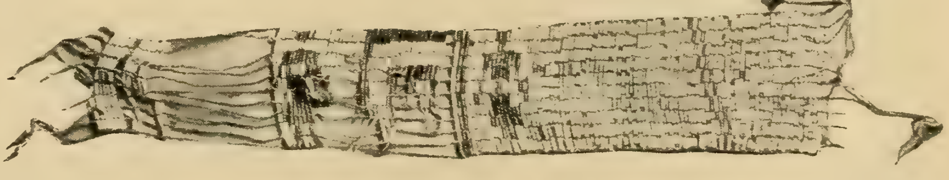
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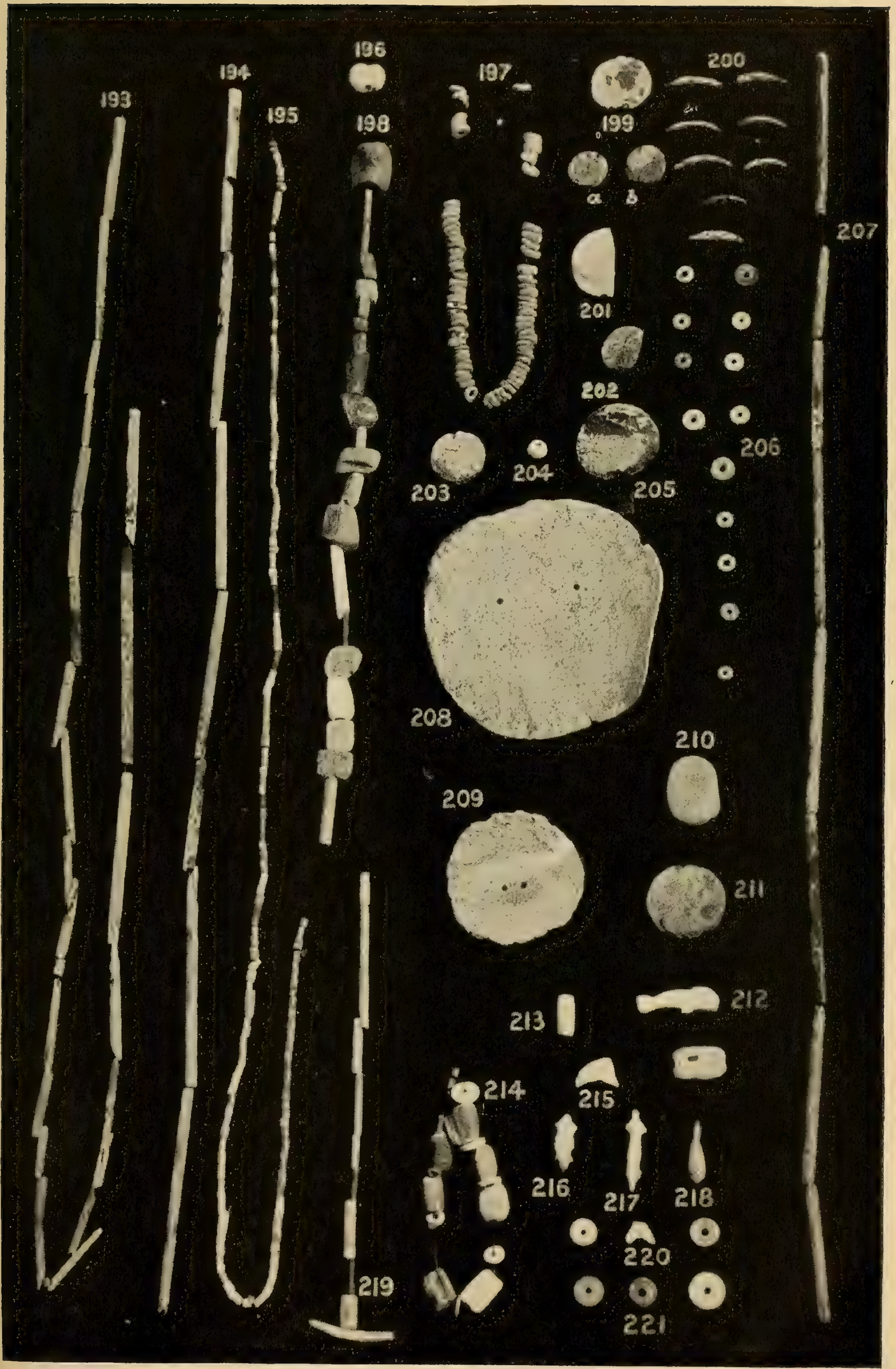

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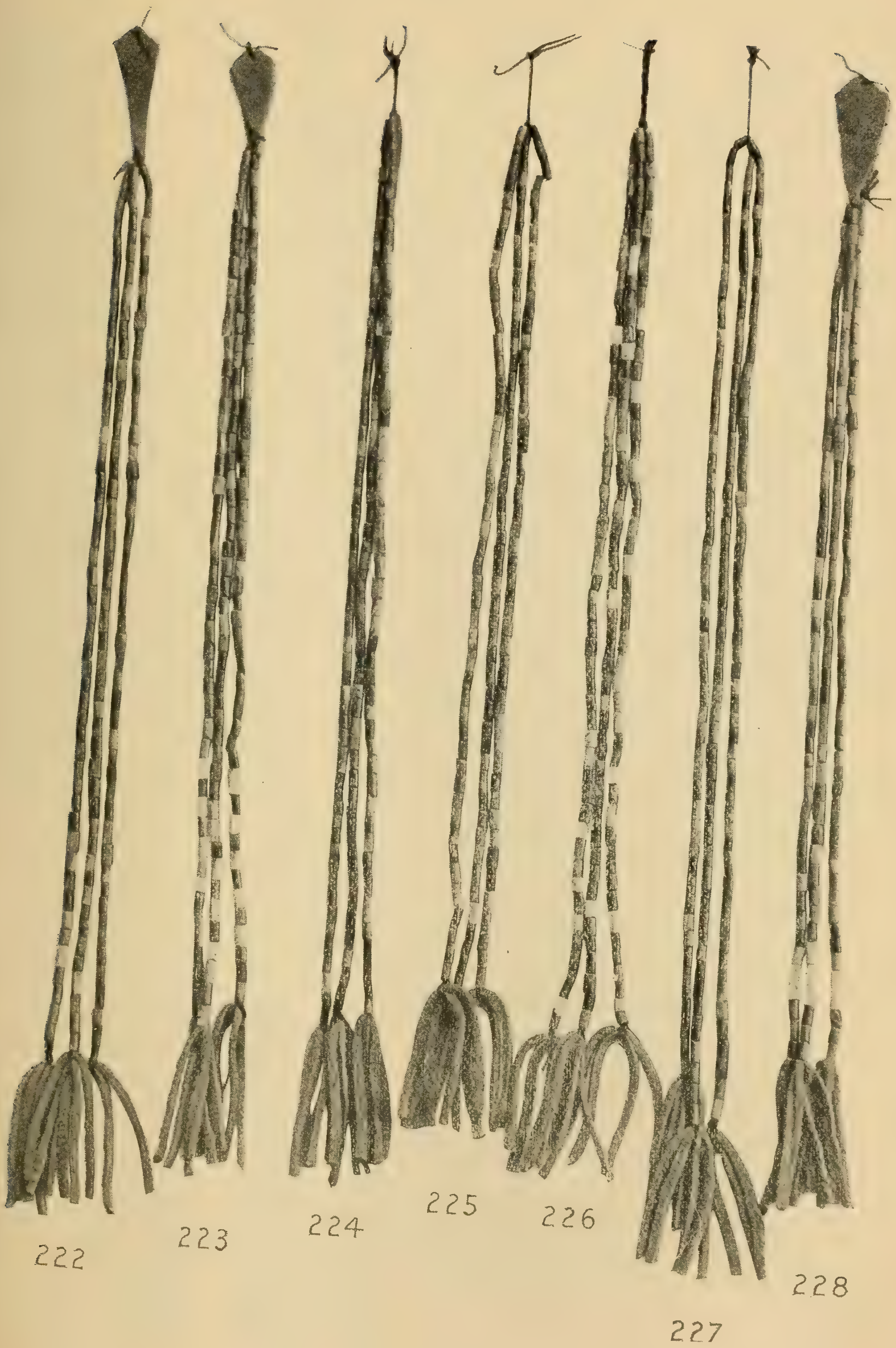

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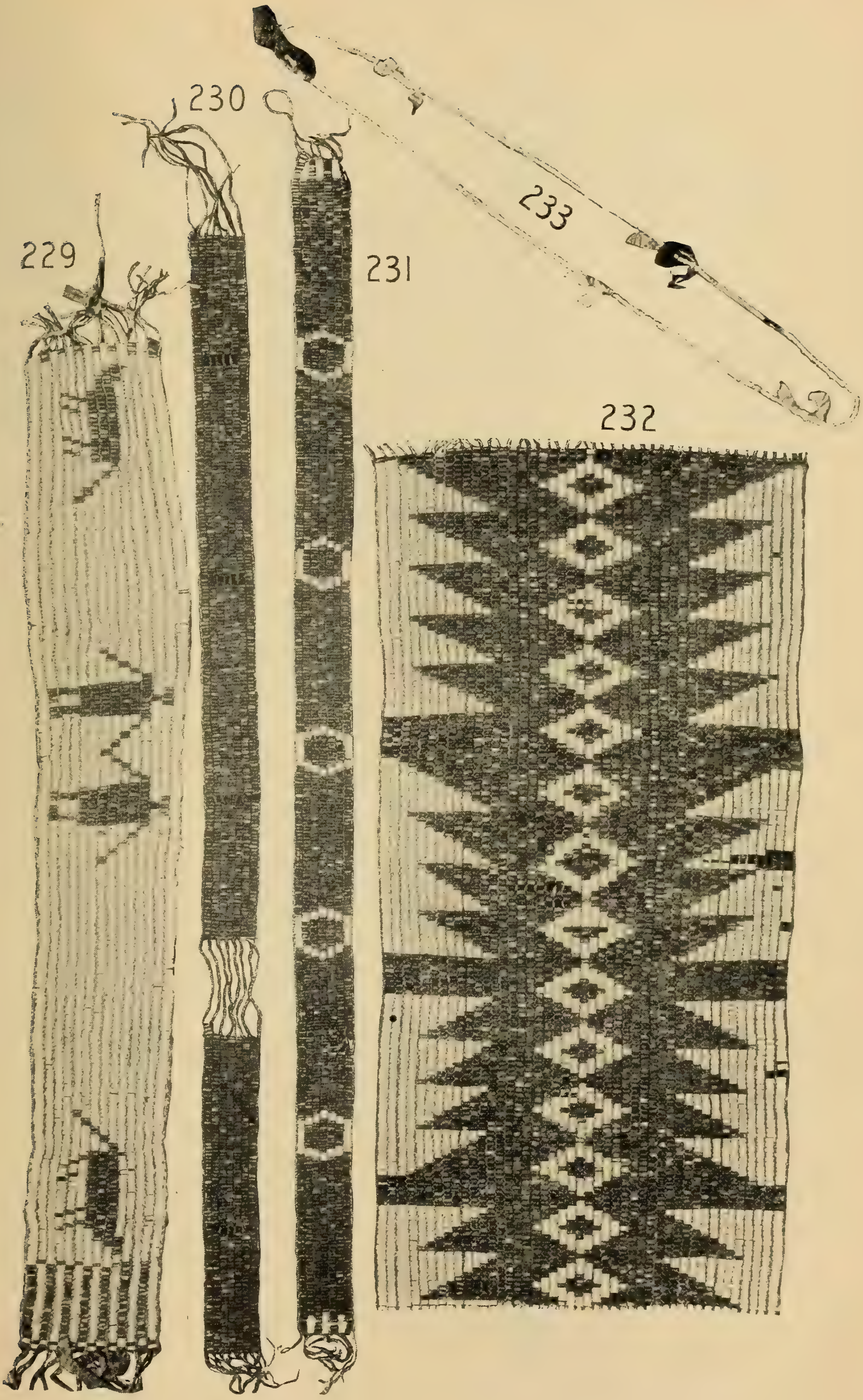

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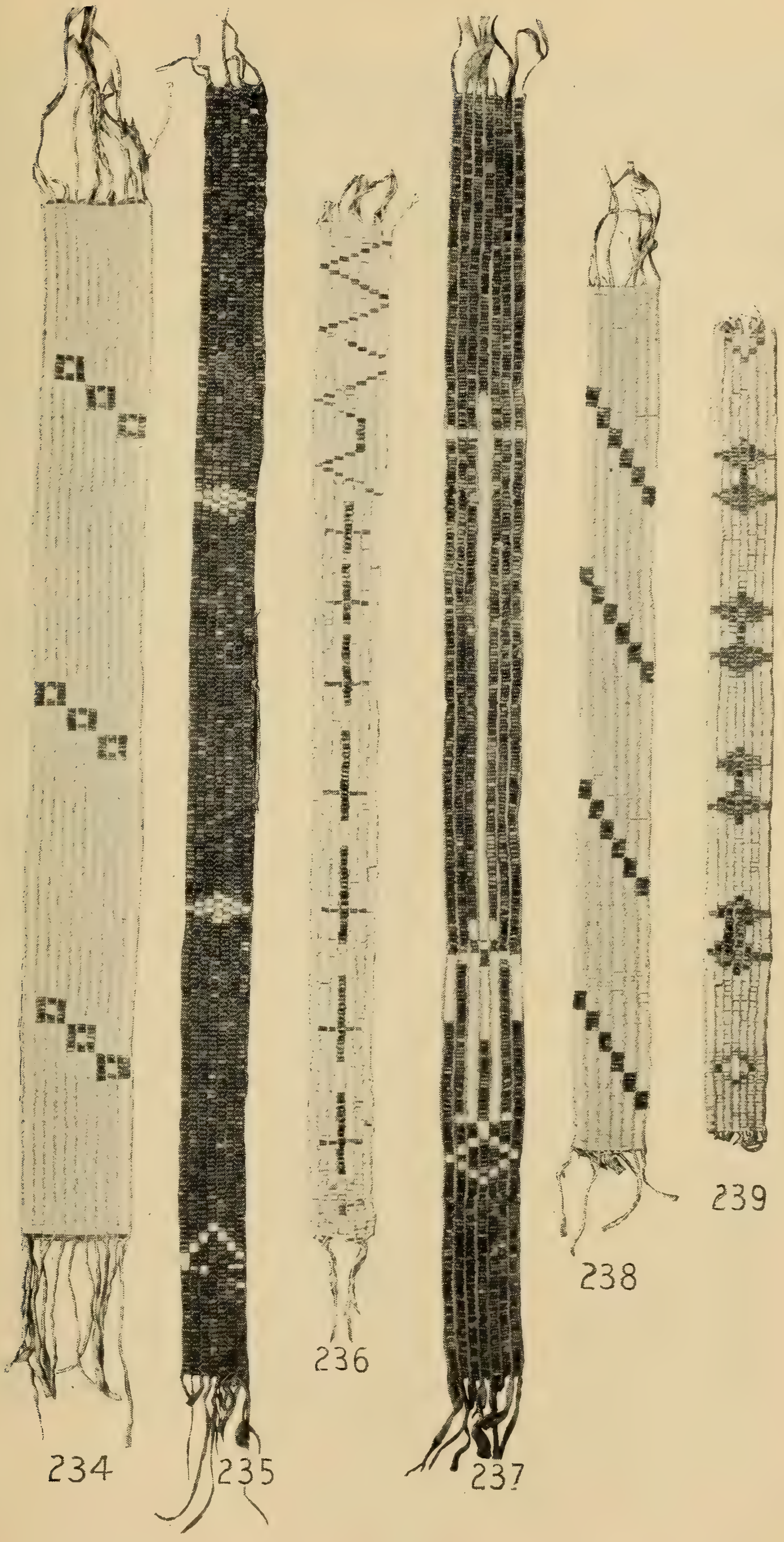

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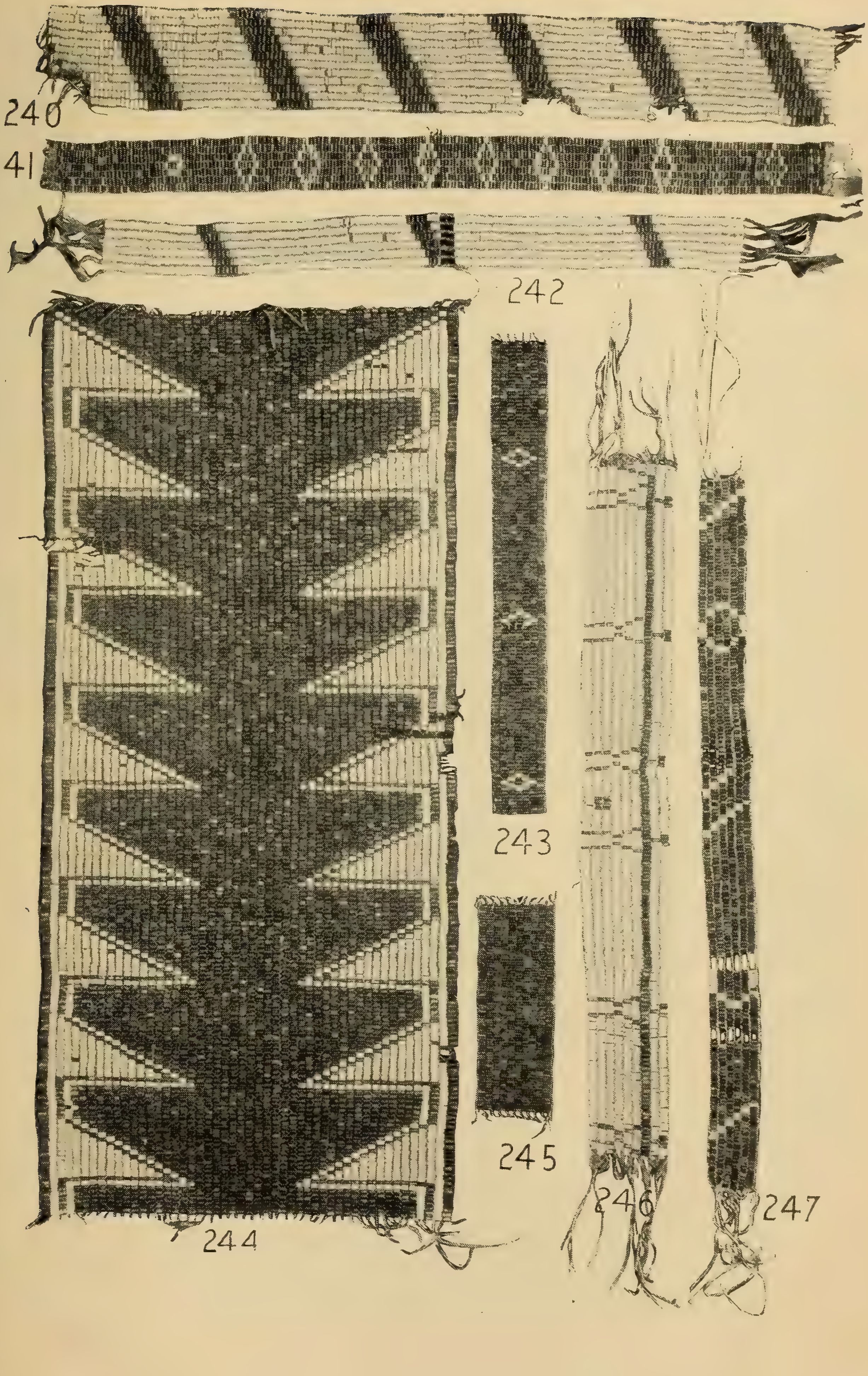

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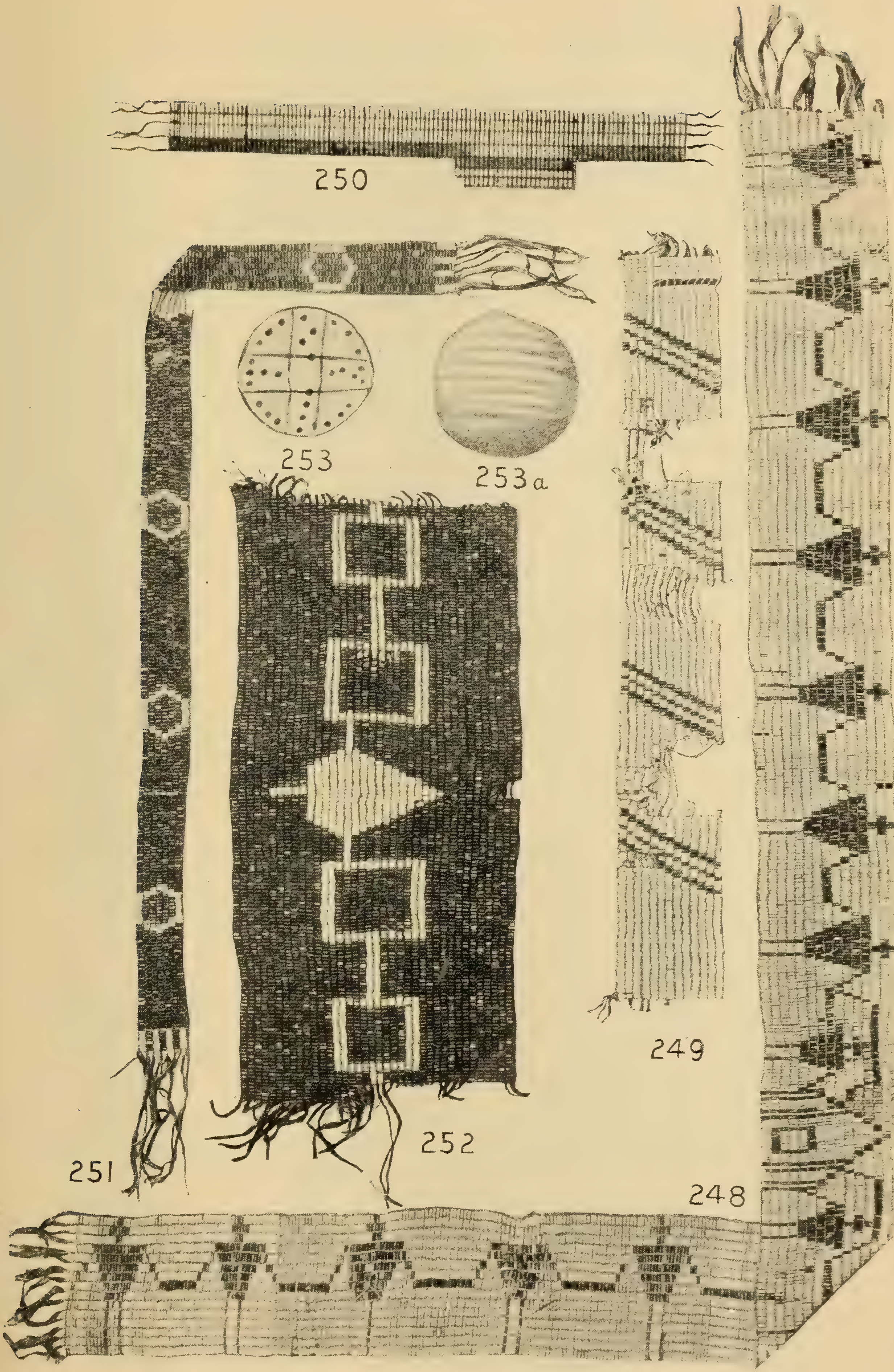

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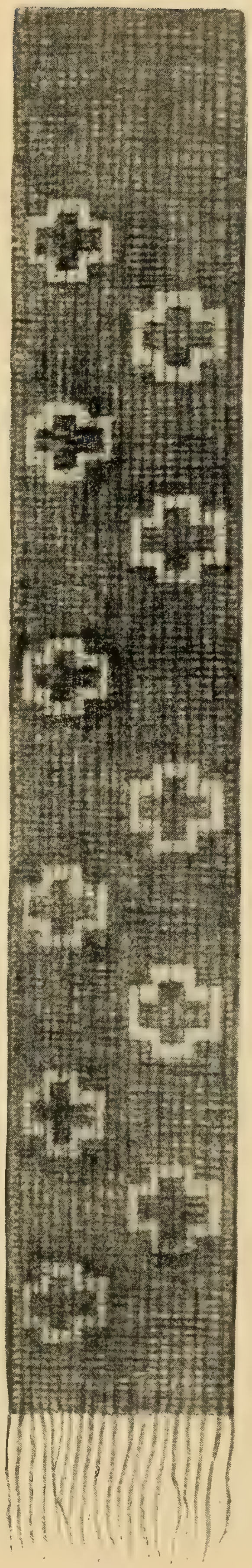
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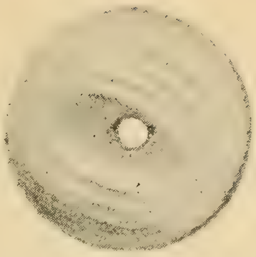
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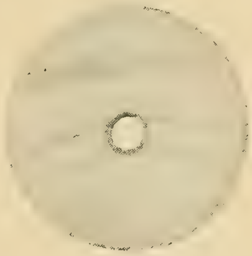
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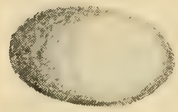
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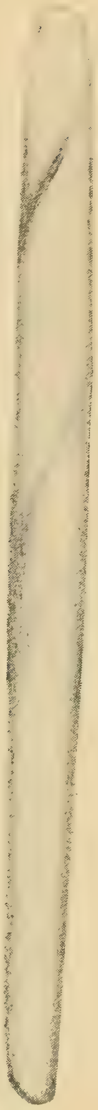
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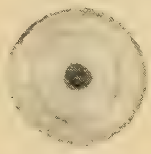
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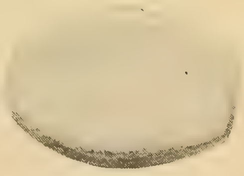
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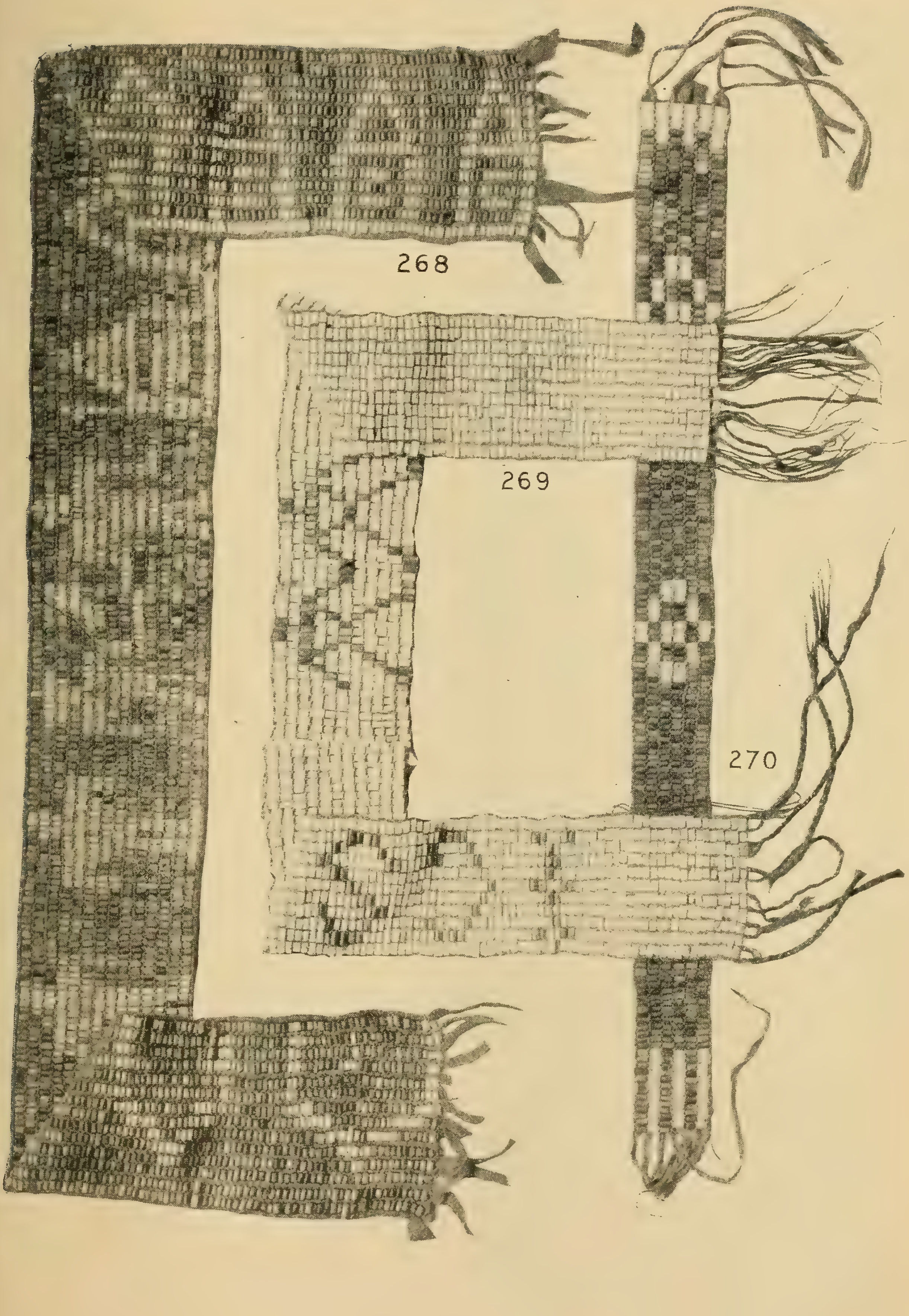

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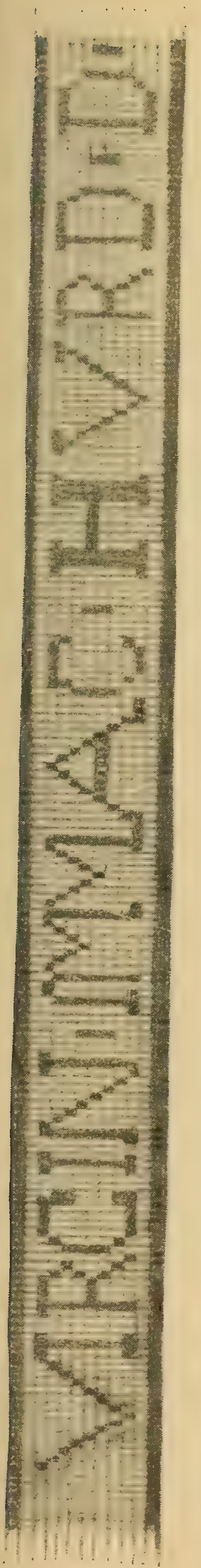

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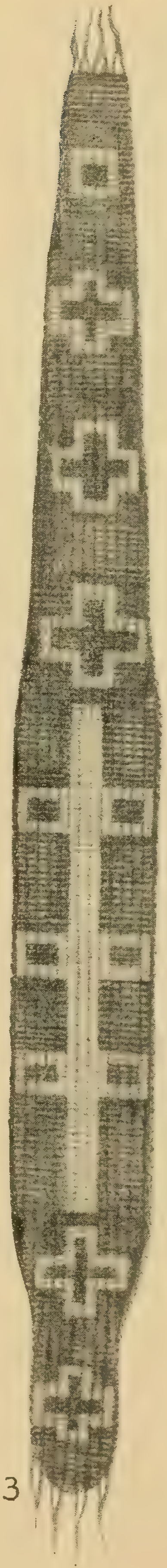

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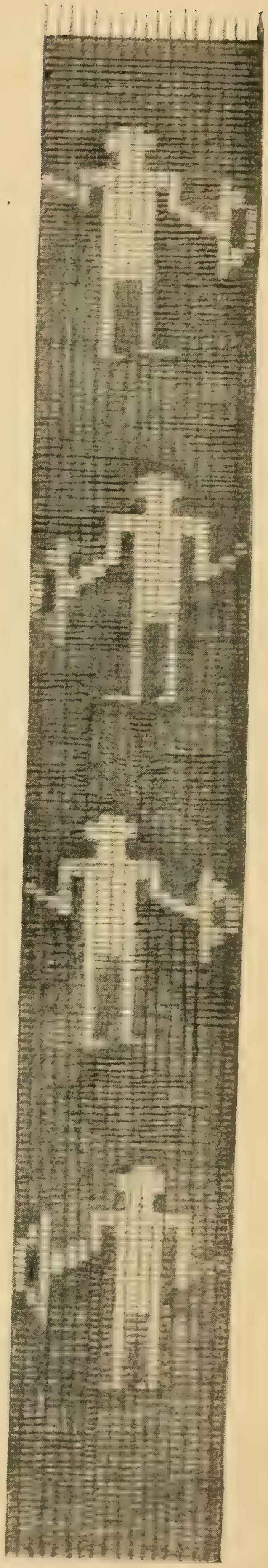

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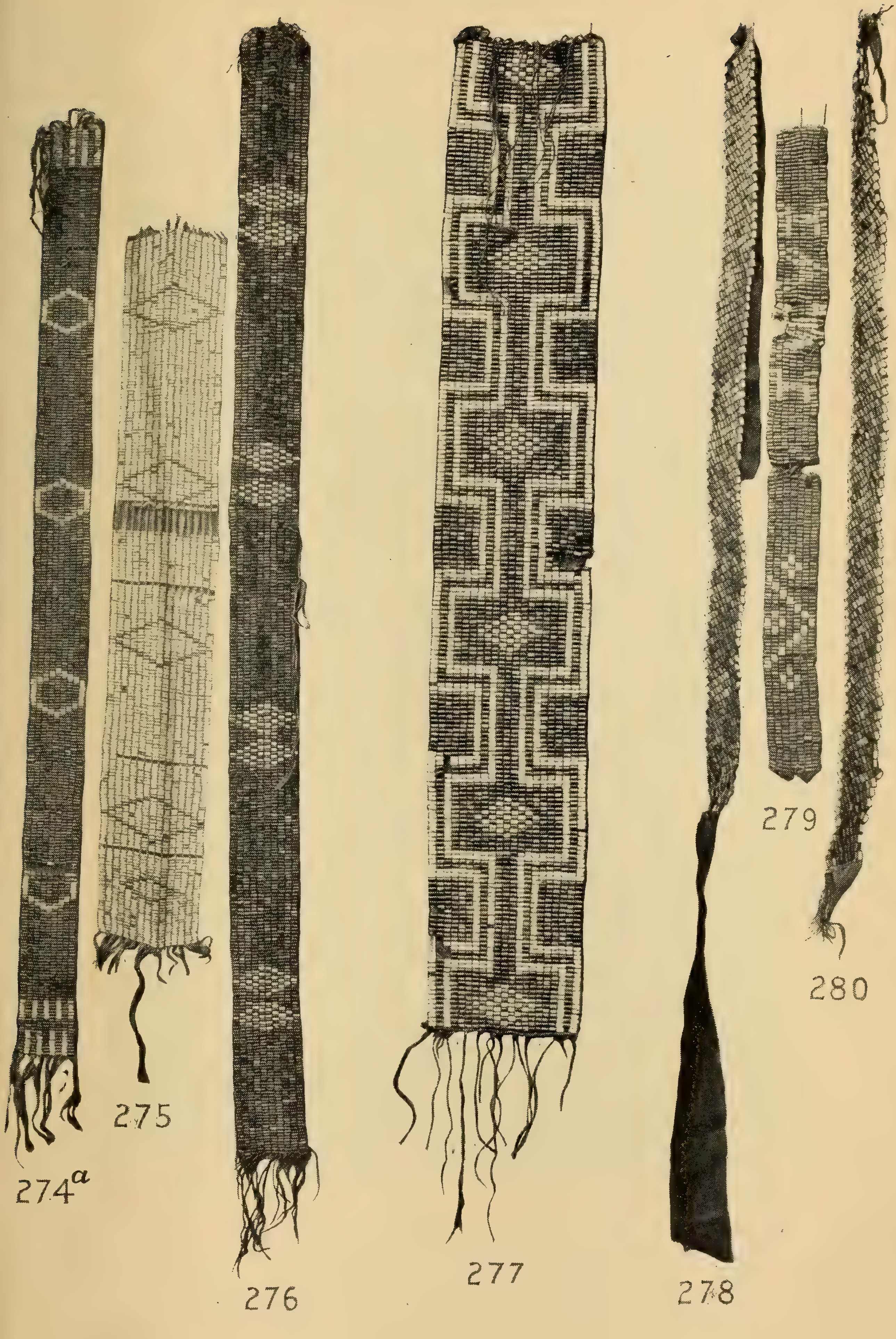

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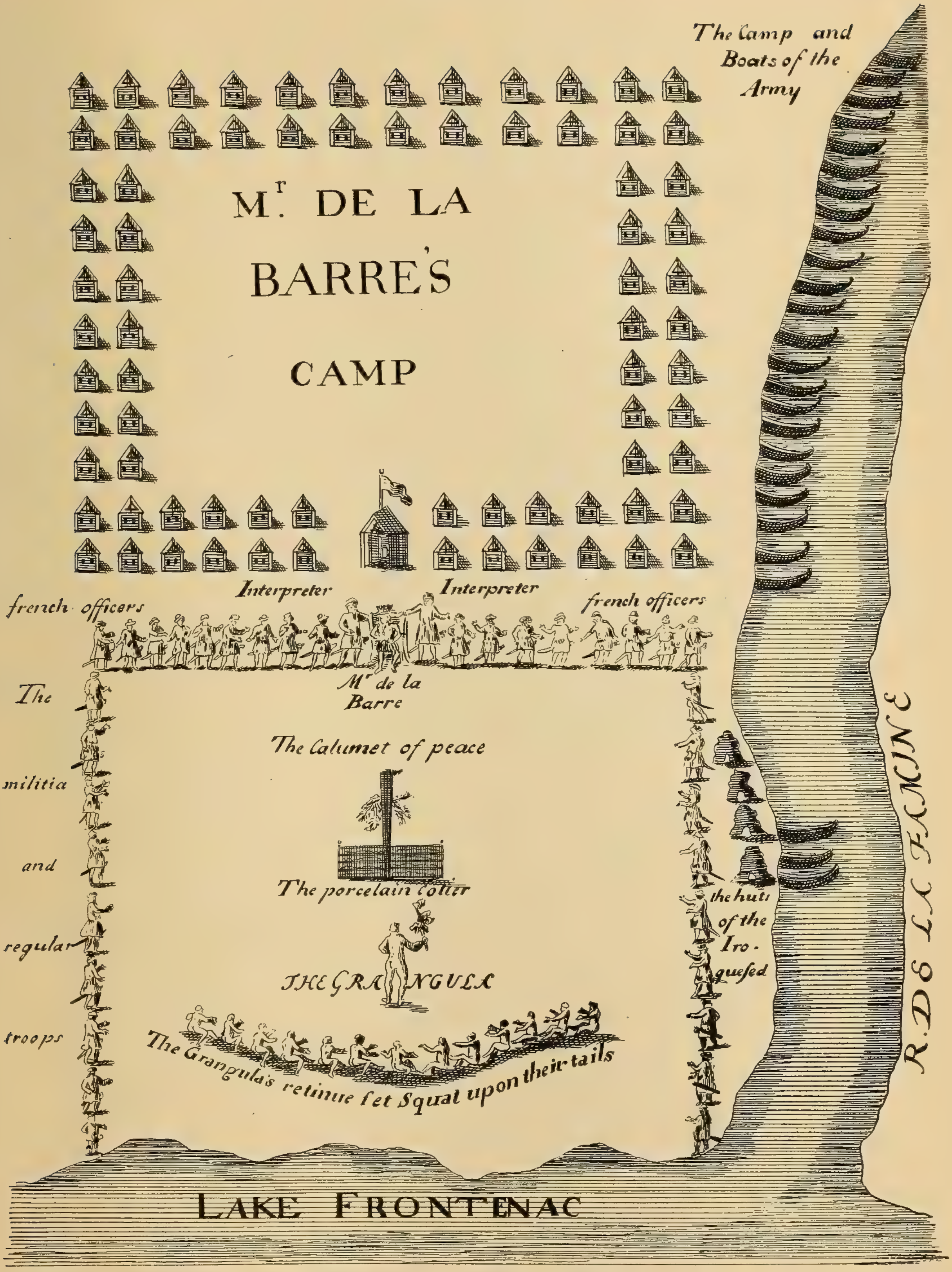
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UNIVERSITY OF THE STATE OF NEW YORK

STATE MUSEUM

BULLETIN No 42

John M Clarke, State Paleontologist

Topography by U S Geological Survey
in cooperation with the
N Y State Engineer and Surveyor
Geology by Rudolf Ruedemann

Contour interval 20 feet
Datum is mean sea level

(Pages 481-82 were bulletin cover pages)

University of the State of New York

BULLETIN

OF THE

New York State Museum

FREDERICK J. H. MERRILL *Director*

No. 42 Vol. 8

April 1901

HUDSON RIVER BEDS NEAR ALBANY

AND THEIR

TAXONOMIC EQUIVALENTS

BY
RUDOLF RUEDEMANN Ph.D.

ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
1901

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HUDSON RIVER BEDS NEAR ALBANY

AND THEIR

TAXONOMIC EQUIVALENTS

INTRODUCTION[1]

The study of a rich graptolite fauna from the vicinity of the city of Hudson, Columbia co., identical with the Normans kill fauna of Kenwood, Albany co., made known by the late Prof. Hall, impressed the writer with the great uncertainty still prevailing among geologists as to the age of these shales and with the wide differences in their stratigraphic assignments by various writers. To illustrate this condition the most important of these differing views may be cited. While Hall finally placed the graptolite-bearing shales of Normans kill above the Utica shale and in the Hudson river beds, asserting their homotaxy with the Lorraine beds, Whitfield and Walcott have considered them a part of the Utica shale formation. Lapworth and Gurley assign them to the Trenton stage, and Ami is inclined to regard them as lying below the Trenton and above Chazy limestone. Frech recently cites graptolites of this zone as from the "Utica shale of Normans kill."

Such an apparent inability to correlate properly a terrane with such a rich fauna would seem inconceivable, specially so in a state which, by the labors of Prof. Hall and of his many followers, has furnished the standard scale of formations for all America, were it not for the indescribably folded, tilted and crushed condition of the beds, the one-sided character of the fauna, and the distribution of the graptolites in thin bands in the otherwise utterly barren, huge mass of shales and sandstones, which, practi-

[1]This paper was submitted Ap. 1, 1900, to the Boston society of natural history in competition for the Walker prize, and a synopsis of the same read before the American association for the advancement of science June 26, 1900.

cally, have discouraged investigators and collectors from studying this unfruitful terrane. Thus, for example, the Hudson river beds were left out of consideration by N. H. Darton in his investigation of the stratigraphy of the formations of Albany county (48)[1].

The writer has tried to approach the problem by systematically visiting and collecting at all outcrops in a rather limited territory, embracing the banks of the Hudson river and its tributaries between Waterford, 8 miles north of Albany, and Coeymans, 13 miles south of Albany. This region contains many of the localities where fossils were found before, and among them also the classic collecting grounds of the Normans kill (Kenwood) and the Abbey (Glenmont). A number of new localities have been found, which, by their arrangement in zones and by their fossil contents, allow a step forward toward the solution of the problem and justify the present publication.

HISTORY OF THE HUDSON RIVER BEDS

The history of the problem of the Hudson river beds has been treated, though only in regard to the validity of the term, by James Hall (17) and C. D. Walcott (36a), to whose papers the reader may be referred here.

W. W. Mather

The term "Hudson river slate group" was proposed in 1839 by Mather, in his annual report on the geology of the first district (1), where he says (p. 212): "(1) The lowest in the series [of fossiliferous rocks] is the *Hudson river slate group*, consisting of slates, shales and grits, with interstratified limestones, all of which occur under various modifications. This group is overlaid unconformably in many places by the various rock formations of more recent origin." The following fossils (graptolites) are mentioned besides a few shells: "Fucoides serra, F. dentatus, and two other species which are probably F. lineatus and F. ramulosus".

[1] *See* References, p. 581.

In the final report of the first district (1843) Lieut. Mather (4) changed the name Hudson river slate group to Hudson river group. Of its fossil contents he reports (p. 369): "These rocks contain *few fossils* except fucoids, and these are extremely abundant in some of the strata. A few specimens of testacea only have been found in this group, although it is well exposed to view over a great extent of country in the first geological district." The strata of the Hudson river group in the northern counties (including Albany county) are described under two heads (p. 375):

1 Those east of the anticlinal axis, which are upturned.

2 Those west of the anticlinal axis which are but little disturbed.

The anticlinal axis above referred to ranges from near New Baltimore by Saratoga lake to Bakers falls.

Of the upturned strata it is said that they all dip eastsoutheast, and in regard to the less disturbed beds Dr Mather remarks (p. 377); "*The horizontal and slightly inclined strata of slates and grits* of the Hudson river group, lying on the west of the anticlinal axis, as traced from New Jersey to Saratoga lake, were *formerly* considered as *more recent strata than the upturned rocks of the Hudson valley, and as resting unconformably on them.* It was not until the labors of the geologic survey were more than half completed, that sufficient evidence was obtained to establish the fact with *certainty* that they are of the *same* geologic age." It is farther stated that the strata could be traced across the line of disturbance only in the Mohawk valley, that however, the Trenton and the Utica formations were recognized in the tilted strata by their fossils, the Utica shale by the graptolites.

It follows from these quotations that Dr Mather distinctly correlated the Hudson river beds with the Lorraine beds, or rather with the Frankfort slates of the Mohawk valley, that he farther believed that the Trenton and Utica beds could be recognized in the Hudson valley. As to the latter, it is evident from his description of the Utica slate that he did not yet discern between the Normans kill graptolites and the Utica shale graptolites and considered all graptolite-bearing shales as being of Utica age;

for he mentions among the localities of the Utica shale such typical collecting grounds of the Normans kill fauna as the banks of the Normans kill itself, the Kinderhook creek and the city of Hudson. Misled by the supposed identity of the two graptolite faunas which later were separated by Hall, he considered the Normans kill shales as homotaxial with the Utica shale. This wrong conception has apparently mislead still later writers.

Lardner Vanuxem

Lardner Vanuxem (5), like all the members of the survey, accepted Mather's term and called all the beds between the Utica shale and the gray sandstone of Oswego, the Hudson river group, but pointed out, that there are two divisions which are not coextensive, embraced by this term, namely, a lower one (the Frankfort slates) which passes from the Hudson valley through the Mohawk valley and extends north by Rome through Lewis county into Jefferson county; and an upper division (the Pulaski shale), which first appears in Oneida county and extends from thence north and west. Fossils are rare in the Frankfort slate, but are numerous where it joins the next series, the Pulaski beds. They have been reported from near Rome, Westmoreland and Utica, and also from Cohoes near Waterford, though the species are not enumerated.

It is obvious that Vanuxem correlates only the lower or Frankfort slates with the beds of the Hudson valley.

Ebenezer Emmons

In the same year Dr Emmons (3) described shales of the Hudson valley as the *Hudson river series* or *group* and stated their extension northward through New York and Vermont to Quebec and through Pennsylvania into the southern states. He proposed the name "Lorraine shales" in place of the names "Pulaski shale" and "Hudson river shale," used before, on the ground that at Lorraine alone a complete section with the top and bottom of the group exposed, could be found (3:119). This term has since been struggling for ascendancy with the term, Hudson river beds.

James Hall

Hall, in his report on the fourth geological district (6), also accepted the term Hudson river group, but remarked that along the Hudson river, where disturbance has prevailed, the Utica shale and Hudson river group are not easily separable (6:30). He, hence, assumed the presence of Utica shale in the Hudson valley.

In 1847 the same author furnished the means of separating the two formations by describing the fossils of the Hudson river group (7). The fossils described under the caption "Hudson river group" are components of two entirely different faunas, the mollusk fauna of the Lorraine beds of northwestern New York and the graptolite fauna of Normans kill. That Hall retained Mather's and Vanuxem's views of the homotaxy of the Hudson river beds with the Frankfort beds seems to the writer to have been caused principally by the finding of Frankfort slate fossils (Modiolopsis nuculiformis, Cleidophorus planulatus, Lyrodesma pulchella, Murchisonia gracilis, Carinaropsis patelliformis, C. orbiculatus, Bellerophon cancellatus), and of Ambonychia radiata, which is characteristic of Vanuxem's upper division, in the Hudson river shales of Waterford (*see* localities of these fossils in v. 1, *Pal. N. Y.*) These fossils seem, indeed, to connect the western fauna with that of the Normans kill beds, but it may be remarked here that the writer has obtained evidence showing that these mollusks nowhere occur in the same beds with the Normans kill graptolites, but in actual Lorraine beds which are stratigraphically widely separated from the graptolite beds. That Hall himself did not feel sure of his correlation becomes evident from an interesting footnote on page 329 of the above cited fundamental work.

This uncertainty may also explain why in the third volume of the *Paleontology of New York* (8: 14), Hall extended the term Hudson river group to "all the beds from the Trenton limestone to the Shawangunk conglomerate," an extension of the term

which has been taken up by the textbooks and has come into general use.

In the same volume Hall described some new graptolites from the Point Lévis shales of Canada as coming from near the summit of the Hudson river group (p. 503), a correlation to which exception was taken by Billings (9), who not only claimed a greater age for the Point Lévis and Quebec, but also for the Normans kill graptolites. Billings derives his conclusion from a comparison with the vertical range of the graptolites in England, a proceeding which, 25 years later, was repeated by Lapworth and, interestingly enough, with similar results. This paper of Billings's is indicative of the complete change in the correlation of the Hudson river shales which, about this time, was wrought by the influence of the Canadian survey. The latter, influenced by the presence of primordial fossils in the Hudson valley region, assumed that the older rocks of Canada and of the Champlain valley extended into the Hudson valley. The influence of Emmons, who had extended the term, Taconic, to the shales of the Hudson valley and asserted the continuation of the Hudson river shales to the primordial region of Quebec, was also powerful in shaping Hall's view of the older Lower Siluric age of the Hudson river shales. When Hall received the graptolites of the Canadian survey for description, and believed that he recognized in species from Point Lévis and other localities on the St Lawrence below Quebec, Normans kill species, he came out openly (10) for the "primordial (Quebec) age" of the bulk of the Hudson river beds, assuming with Logan, that the two or three occurrences of a few fossils of the "second fauna" were "outliers of insignificant extent embraced within the folds of the older rocks or resting upon these primordial beds which formed the fundamental rocks of the valley, and that the deranged and altered Hudson river beds were separated from the unaltered beds in the west by a fault". He, therefore, dropped the term Hudson river group, stating expressly (10:444) that the graptolites of the Hudson valley do not belong to the second fauna, but "hold a lower position and belong to the great mass of the shales below".

But Hall soon discovered his error in regard to this correlation with the Point Lévis graptolites and protested against the inclusion of the Hudson river graptolites with those of the slates of Point Lévis; as a consequence of which they were omitted from the report of the Canadian survey (decade 2) after having been figured.

Soon still more facts began to accumulate which threw doubt on that correlation, and finally, in 1877, Hall read a paper (17) before the American association for the advancement of science, in which the famous investigator fully relates how in joint excursions with his friend, Sir William Logan, along the Hudson river and the adjacent counties, the evidence on which the original conclusions were based, was reviewed. He said:

> A farther careful study of the materials collected showed conclusively that, within the limits indicated, all the fossils were of the second fauna. Many of the species of graptolites, so abundant in certain localities of the disturbed and partly altered shales, were also found in the shales and sandstones which gradually assumed an undisturbed and unaltered condition within a few miles west of the river, extending thence through the Mohawk valley, where they rest conformably upon the limestones of the Trenton group.

With this declaration Hall returned to his former view of the continuity of the graptolite-bearing beds of the Hudson river shales with the Frankfort slates of the Mohawk valley and the Lorraine beds of the northwestern region. It is a misfortune that he does not specify the many species of graptolites which he says are common to the altered shales of the Hudson valley and to the more western undisturbed beds, as this observation forms the principal base of his correlation and has not been verified by other observers, while it disagrees with the writer's results on the distribution of the Normans kill fauna to the west of the Hudson valley.

The cause of the misinterpretation of the rocks of the Hudson valley is, in the same address (17:261), very appropriately attributed to the "fact, that not only the rocks in the immediate valley of the Hudson, but also those between the river and the eastern limit of the state, were treated as a single group or sys-

tem of rocks, and belonging to one geologic age, thus creating confusion in whatever aspect they were regarded". The occurrence of lithologically homogeneous, but faunistically heterogeneous terranes, forming apparently a stratigraphic unit, has been the cause of endless discussion and confusion, as the Taconic, Quebec and this, the Hudson river group controversy fully demonstrate. It appears, now, that, while Hall freed the Hudson river group, by insisting on its upper Champlainic (Siluric) age, from being farther involved in the Taconic controversy, he, to a certain extent, committed a similar error by uniting the Lorraine and Normans kill faunas in one group, for this correlation is, as will be shown still farther on, the principal cause of the controversy in regard to the age of the Hudson river group.

R. P. Whitfield

The composite character of the Hudson river beds was first positively asserted by R. P. Whitfield in a letter written in 1875 to Dr C. A. White (16). Prof. Whitfield's most important statements in regard to our investigation are:

> From the evidence furnished by these fossils (graptolites), I have reached the conclusion that the graptolite-bearing layers there are of the age of the *Utica slate*, the following being a summary of the facts I have observed.
>
> I have found the following species common to both the graptolite layers at Normans kill and those of the Utica slate formation at the mouth of Oxtungo creek near Fort Plain N. Y.: Graptolithus (Monograptus) serratulus, Hall, G. (Diplograptus) pristis, Hall (not Hisinger), G. (Climacograptus) bicornis, Hall and G. (Dicranograptus) ramosus, Hall.
>
> Just south of Troy, in the shaly partings between layers of metamorphic limestone, I have found a species of graptolite in great abundance indistinguishable from G. amplexicaulis Hall from the Trenton limestone of Herkimer county, N. Y. The same species was also found abundantly in the yard of the arsenal at Watervliet by Capt. C. E. Dutton, U. S. A.
>
> From the foregoing facts I infer that the slates below Troy and in the arsenal yard, together with the associated metamorphic limestones, are the equivalents of the Trenton limestone.

The most interesting discovery of Whitfield's is that of the presence of shales of Trenton age among the shales of the Hudson valley. The writer has carefully compared specimens of the graptolite in question found at the arsenal yard and preserved in the state museum with the D. amplexicaulis found in the Trenton limestone at Middleville and is convinced of their identity. Besides this graptolite other fossils have been found in the shales and calcareous sandstones (not limestone) of south Troy and the neighborhood of the arsenal which more firmly establish Prof. Whitfield's discovery.

The supposed homotaxy of the Normans kill fauna with that of the Utica shale is based on the occurrence of four graptolites in both faunas. Of these the presence of Didymograptus serratulus in the Utica beds has not been verified by other collectors and is doubted by Lapworth and Gurley; Hall's Diplograptus pristis, however, is partly identical with Hall's D. quadrimucronatus, which is very common at Fort Plain as everywhere in the Utica shale, and which at that time was considered also by Hall as occurring only at the locality from which it was first made known (Lake St John, Canada), and partly identical with Diplograptus foliaceus, Murchison.[1]

The two forms, D. foliaceus and D. quadrimucronatus, are not always easy of separation, when completely flattened in the shales; and the writer also has, following Hall's example and identification, described colonies of D. quadrimucronatus as belonging to D. pristis Hall. Fritz Frech (54:626) supposes this large mucronate form of the Utica shale to be D. whitfieldi, Hall. A detailed account of all these forms will be given by the writer in another paper.

Climacograptus bicornis and Dicranograptus ramosus are, indeed, common to the Normans kill and

[1]Diplograptus quadrimucronatus is restricted to the Utica shale, and for this reason, can not be adduced as connecting the Utica and Normans kill shales; Diplograptus foliaceus, which is more common in the Normans kill shale, ranges from the Chazy to the Lorraine beds and hence is of no taxonomic value.

Utica shales, as declared by Whitfield. These two, however, appear insignificant when compared with the great number of differing graptolites in the two zones, specially when the entirely different aspect of the two faunas is taken into consideration; for, while the Normans kill fauna as to prevailing species and individuals is characterized by branching forms, notably of the genera Coenograptus, Didymograptus and Dicellograptus, the Utica shale fauna is almost entirely composed of Diplograptidae and Climacograptidae and bears in its genera and species a decidedly younger character than the Normans kill fauna, as becomes apparent by a comparison with the vertical range of the same forms in Sweden and Great Britain. In fact, to the time of his death Hall insisted on the different age of the two faunas, as the writer can assert by personal information from the genial paleontologist.

The concurrence of the two graptolites will indicate hardly more than the Middle Champlainic (Siluric) or Mohawkian age of the Normans kill beds.

The Cohoes beds which Whitfield believes to be of equal age with the Normans kill beds are homotaxial with the Lorraine beds, as already suggested by the Trinucleus concentricus collected in them by Whitfield. They are evidently the same beds from which Hall reports such typical Lorraine fossils as Ambonychia radiata and in which also the writer has found an undoubted Lorraine fauna. In regard to the Lorraine beds, however, which Whitfield supposes to occur close to the Normans kill graptolite beds along the Normans kill, the writer has not been able to obtain any data, but he believes the small Diplograptus on which Whitfield principally bases his correlation to be the Diplograptus putillus of the Utica shale, which has been found by the writer in several localities farther up the Normans kill.

C. D. Walcott

Four years later, in a paper read before the Albany institute by C. D. Walcott (36a), the Normans kill beds were included in the Utica slate (as "Utica slate 2"—*see* the catalogue of fossils,

p. 34, *op. cit.*), obviously on the ground (p. 2) "that the Utica slate formation was traced by the New York geologists down the Mohawk valley from Oneida county through Herkimer, Montgomery, Schenectady and Saratoga counties to the shores of the Hudson", and that "Prof. W. W. Mather gives the following localities in the Hudson river valley below Bakers falls, where the Utica slate is to be observed with its characteristic graptolities, at Waterford, Cohoes, Normans kill below Albany, at Hudson," etc. The evidence which the graptolites at Normans kill afforded to Whitfield of the equivalency of the graptolitic slates and the Utica slate, is also cited.

As these citations prove, Walcott based his correlation on the continuity of the shales of the Mohawk valley with those of the Hudson valley and on the Utica slate localities in the Hudson valley as mentioned by Mather, and finally on Whitfield's assertion of the partial identity of the Normans kill and Utica faunas. The first argument has been meanwhile weakened by the establishment of the presence of a fault between the disturbed and undisturbed regions, which was already assumed by Emmons, and will be spoken of farther on (p. 504). Mather's assertion of the presence of a zone of Utica shale localities in the Hudson valley was caused, as shown above, by his failure to distinguish between the Normans kill and Utica shale graptolites; and Whitfield's correlation has just been discussed on the preceding pages.

T. N. Dale

In the same year T. Nelson Dale (20) discovered in an outcrop of argillaceous schist about a mile west of the Hudson opposite Poughkeepsie, crinoid stems, Orthis testudinaria, O. pectinella, Leptaena sericea, Strophomena alternata, Bythotrephis subnodosa and a cast of a gastropod which resembles Bellerophon bilobatus (all being Hall's identification), some of these fossils being also found near Vassar college and south of Poughkeepsie.

The author concludes from his determinations that "the clay slates and shales in the vicinity of Poughkeepsie, on both sides of the river, are fossiliferous and that they very probably belong

to the Hudson river group, as indicated by Mather in 1843, and certainly to some member of the Trenton period ".[1]

But it seems to the writer that the evidence afforded by these fossils has been here somewhat strained to bring the facts into accordance with Hall's views; for, while Orthis testudinaria, Leptaena sericea, Strophomena alternata, Bellerophon bilobatus are noncommittal, occurring from the Trenton to the Lorraine beds, and Bythotrephis subnodosa, being a rather indistinct plant fragment, is of little or no taxonomic value, Orthis pectinella is declared by Hall himself (7:123) to occur in nearly every part of the Trenton limestone, though unknown to him in the Hudson river group. Theodore G. White, in his very useful paper (51:83, 94), reports the form only from a six foot bed overlying the Black river limestone of the Poland limekiln section. In the Cincinnati region and in Canada the fossil is found in the Black river and Trenton beds, and Winchell and Ulrich announce it in their carefully prepared lists only from the upper Black river beds of Minnesota (49).

The evidence afforded by the fossils of Poughkeepsie would then rather indicate for these Hudson river schists the age of the Trenton limestone.

J. D. Dana and W. B. Dwight

At the same time the problem of the Hudson river shales was approached from the east by James D. Dana (21), who found that the five limestone belts traversing the schists east of the Hudson river are anticlines of limestones, underlying the schists. He also succeeded in finding fossils in the limestones which were described by W. B. Dwight (23), as denoting a Trenton fauna. Dana, therefore, concluded that the "Taconic schists" overlying the limestone are of Hudson river age.

Dwight cites the following fossils: Orthis tricenaria, O. pectinella, O. testudinaria, Leptaena seri-

[1]Dana had meanwhile (Manual of geology. 1874) proposed to unite the Trenton, Utica and Cincinnati (= Lorraine) epochs under the term Trenton period.

cea, Strophomena alternata, Escharopora recta, Ptilodictya acuta, caudal shield of a small trilobite probably Asaphus vetustus, Endoceras (probably proteiforme), Orthoceras, not well defined, spiral univalves, Chaetetes named Ch. tenuissima, encrinal columns, Receptaculites.

In another paper (24) the same investigator states that the Chaetetes with fine columns has been identified, in part at least, as Stromatopora compacta, Billings, and adds as new from Rochdale a number of Cyathophylloid corals, among them, with little doubt, Petraia corniculum, a caudal shield of a trilobite which has been identified by Ford as Illaenus crassicauda, and a head of Echino-encrinites anatiformis.

He also found in the continuation of the limestone belt across the Hudson, 2¾ miles north of Newburgh ferry: Orthis lynx, O. pectinella, Rhynchonella capax, Leptaena sericea, Strophomena alternata, a new Discina (later described as D. conica), Chaetetes compacta, very abundant, Ch. lycoperdon var. ramosus, Schizocrinus nodosus, Echino-encrinites anatiformis, probably O. tricenaria, and Petraia corniculum.

The author adds: "These developments establish this beyond doubt as a stratum of the Trenton limestone". A farther conclusion which could be drawn, is that these faunas contain no forms characteristic of or restricted to the upper Trenton, while they distinctly point to a lower and perhaps in some degree middle Trenton age for the beds; for Orthis tricenaria and Petraia corniculum are restricted to the lower Trenton, Illaenus crassicauda occurs in the upper Lowville and Trenton limestone, Schizocrinus nodosus is most abundant in the lower Trenton, Ptilodictya acuta and Escharopora recta occur only in the lower and central part of the Trenton, Echino-encrinites anatiformis is a middle Trenton form, and the abundant Chaetetes compacta is restricted to the Black river.

The middle and upper Trenton must, hence, be either absent or represented by shales of the appearance of the Hudson river shales. The latter conclusion seems the most acceptable to the writer as it agrees with his own results obtained around Albany.

C. E. Beecher

The next important discovery of fossils in the Hudson river series of shales was made by C. E. Beecher in the shales near the old Dudley observatory, a short distance northwest of Albany (26). The following fossils were identified: Climacograptus bicornis, Dicranograptus ramosus, Diplograptus mucronatus, crinoid stems, Trematis terminalis, Leptaena sericea, L. subtenta, Orthis testudinaria, Zygospira modesta, Avicula trentonensis, Cleidophorus planulatus, Ambonychia undulata, Tellinomya dubia, T. levata, Lyrodesma poststriatum, 10 undetermined species of lamellibranchiata, Hyolithes americanus, H. sp.?, Bellerophon bilobatus, B. cancellatus, Murchisonia gracilis, Endoceras proteiforme, Orthoceras bilineatum?, Cornulites flexuosus, Plumulites sp.?, Triarthrus becki, Trinucleus concentricus.

Beecher referred this fauna to the Utica epoch, and Walcott (36a : 345) later declared it to be "as a whole, characteristic of the upper portion of the Utica shale in the Mohawk valley and of the passage beds between the Utica shale zone and the lower portion of the Lorraine shales in the section at Lorraine, Jefferson co. N. Y."

The import of this discovery is that it establishes the hitherto only suspected presence of the Utica shale among the shales of the Hudson valley, but it does not warrant the conclusion of the Utica age of the Normans kill graptolite fauna, for of the three graptolites found by Beecher, two, Climacograptus bicornis and Dicranograptus ramosus, are common to both the Normans kill and Utica faunas, and the third,

identified as Diplograptus mucronatus, but unquestionably a new species, is one of the small mucronate forms of the Utica shale not occurring in the Normans kill fauna.

S. W. Ford

In the next year, the untiring collector, S. W. Ford, reported the discovery of another interesting locality at Schodack Landing, to the southeast of Albany, on the east bank of the Hudson river (29).

He found the slates excellently exposed, though bent and contorted almost beyond description, in two promontories, where a band of black slates yielded the characteristic Normans kill fauna, and "at once resolved to institute a careful search for other fossils in the rocks of the neighborhood"; in which endeavor he was very successful, for a bed of limestone about 2 feet thick, and in part somewhat brecciated in appearance, inclosed in the slates, was found. This yielded the following species: Asaphus platycephalus, Calymene senaria, Orthis testudinaria, O. lynx, Leptaena sericea, Strophomena alternata and the hemispheric form of Chaetetes lycoperdon. He concluded: "None of the spècies of this locality are distinctive of the Utica slate, and both the limestone and its associated graptolitic slates represent in my estimation the Hudson river group." These fossils are, however, not restricted to the Hudson river group and would prove only that the Normans kill graptolite shales may belong anywhere from the base of the Trenton to the Lorraine beds.

In another paper (30), Ford discussed the age of the slaty and arenaceous rocks in the vicinity of Schenectady, which by Mather, Emmons and Whitfield have been considered to be of Lorraine age. Ford found at Schenectady Graptolithus pristis, Gr. mucronatus (that is, a mucronate Diplograptus), Triarthrus becki and a Lingula, which he considers to be Lingula curta. On the strength of this evidence he regards the Schenectady beds as of Utica age. This result, if farther verified, would be interesting in so far as it would show

that the Utica beds change toward the Hudson valley in lithologic character and approach more closely the aspect of the Lorraine beds; and hence the former could not be recognized in this region by their lithologic character, as former geologists have attempted to do.

It is farther stated by Ford that "the rocks at Schenectady continue to the eastward to Rexford Flats where a break occurs, and from that point all the way to the Hudson the rocks are greatly tilted. The break here alluded to, Dr Emmons considered identical with the fault occurring at Saratoga Springs and Bakers falls, and believed it to pass somewhere between Albany and Schenectady, and to be traceable in its effects as far south as Kingston." The demonstration of this break between the tilted strata of the Hudson river region and the undisturbed beds of the Mohawk valley is of great importance for our investigation, as it refutes the argument presented by Mather, Hall and Walcott, that the Hudson river beds of the Hudson river region are continuous with and can be traced along the Mohawk valley to the Utica and Lorraine beds of that valley. As the lamellibranchs, cited by Hall from Cohoes, and other fossils found by the writer at the same locality (*see* farther on) prove, the Lorraine formation is well represented at the lower Mohawk, while on the western side of the fault, the Utica shale, as claimed by Ford, may be found. Hence there is no continuity along the lower Mohawk. Similarity of lithologic characters can, in the great mass of similar argillaceous shales, arenaceous shales, sandstones, grits and argillites, representing the Hudson river series of beds in the Hudson valley, only, if ever, be relied on in distinguishing the formations after the most minute study of these lithologic characters. The description of the localities in another part of this paper will bear out this statement.

N. H. Darton

The same fruitful year brought out another discovery of fossils in the Hudson river shales, that by Nelson H. Darton (32) near Sugar Loaf, 2[illegible] miles southwest of Newburgh and at

Walden, on the banks of the Wallkill, 11 miles northwest of Newburgh on the Hudson, two localities in Orange county which were mentioned by Mather. The following fossils (according to Whitfield's identification) were collected: Orthis pectinella, O. testudinaria, O. plicatella, Leptaena sericea, Camarella hemiplicata, Strophomena alternata, Streptorhynchus planumbona or Str. filitexta? and a Trinucleus concentricus. Besides fragments of Chaetetes or Favosites, a crinoidal column and a fragment of Conularia (probably trentonensis).

The greatest interest attaches to Orthispectinella, and Streptorhynchus planumbona or filitexta, as these forms indicate the Trenton age of that shale.

I. P. Bishop

While thus the fortunate discoveries of fossils other than graptolites in the "Hudson river shales" began to furnish evidence of the Trenton age of part of the shales, other investigations, notably those of I. P. Bishop (33) tended to demonstrate the close stratigraphic relationship of the Trenton limestone and the graptolite-bearing Hudson river shales; for, in Columbia county, it was established by Bishop that "the limestone containing Trenton fossils immediately underlies the graptolite shales of the Hudson river group".

Charles Lapworth

An entirely new course to the solution of the problem of the age of the Normans kill fauna was entered on by Charles Lapworth (34), who studied the graptolite faunas from numerous localities in Canada, and sought to determine their age by comparing them with the faunas of the detailed graptolite zones which he had so well succeeded in establishing in Great Britain. A farther innovation in the mode of viewing the problem is implied in Lapworth's suggestion that the Normans kill graptolite beds do not necessarily represent a separate stage in the series of formations but are probably equivalent with certain calcareous strata

of Canada and New York. Lapworth found the Normans kill fauna typically represented at numerous localities and termed it the Marsouin river or Coenograptus zone. This is followed by another zone with a similar graptolite fauna.

As to the taxonomic relations of these two zones, Prof. Lapworth arrived at the following views (p. 170 *loc. cit.*):

There can be no question of the general identity of this Griffin's Cove rock and the Marsouin Coenograptus zone with that of the Normans kill of the Hudson river valley. The New York geologists have always adhered to the opinion that the Normans kill beds are of the age of the Hudson river group (Lorraine) or of that of the Utica slate.

But here we have to recollect that, with the exception of Whitfield's distinct assertion that G. serratulus, Hall occurs in the Utica slate of Oxtungo creek—which may be easily accounted for on the supposition that what Whitfield calls a Didymograptus may possibly be a Leptograptus—not a shadow of paleontologic evidence has yet been adduced to show that these Normans kill or Marsouin rocks are newer than the Trenton.

I will not discuss the evidence further in this place, but will merely say that in Great Britain the fossils of the Coenograptus (Normans kill) zones occur in the beds immediately succeeding the typical Llandeilo limestone of Wales, with Ogygia buchii and Asaphus tyrannus, and in association with the Craighead (Stinchar) limestone of Scotland, with Maclurea logani and Ophileta compacta, i. e. in beds apparently homotaxeous with the Chazy or lowest Trenton (Birdseye and Black river).

If, therefore, we provisionally regard this Normans kill (Marsouin and Griffin's Cove) zone as coming between the Chazy (Maclurea) and the Trenton limestone in America, it will answer roughly to its equivalent, the Coenograptus gracilis zone in Great Britain, in age as well as in fossils.

We must remember that they appertain, possibly, almost to the very lowest beds of that second fauna, i. e. their place is practically Trenton-Utica, and not Utica-Hudson.

E. O. Ulrich

E. O. Ulrich cited some Normans kill graptolites from the Utica shale of Cincinnati (35:183). As these have not been mentioned in later lists of fossils (49), it is probable that they have meanwhile been differently determined, and that the Normans kill zone is not represented in the regions studied by him.

C. D. Walcott

The most careful investigation in the field, bearing directly on the problem of the Hudson river group, has been made by C. D. Walcott (36a). Mr Walcott's working plan was to trace the formations from the undisturbed regions in the northwest and west into the regions of disturbance. These researches gave the following results bearing on our investigation.

The Utica shales can be traced from their contact with the Trenton limestone at the falls of the Hudson near Sandyhill, "with little interruption, to the neighborhood of Albany, where they are very much disturbed and stand at a high angle. In this vicinity the noted graptolite beds of Normans kill occur; also the locality where Mr Beecher discovered the upper fauna of the Utica shale zone". Following up the Normans kill, alternating shales and sandstones are passed over, which "with the same lithologic character" continue across the line of disturbance till the superjacent Lower Helderberg limestone is met with. These shales and sandstones which, at the Indian Ladder, were found to contain Orthis testudinaria and Trinucleus concentricus, are correlated with the Frankfort shales of the Mohawk valley. Mr Walcott's conclusions of the presence of a zone of Utica shales in the Hudson river valley and of the extension of the Frankfort shales along the Normans kill are mainly based on lithologic evidence. Fossils found at numerous localities by the writer have served to verify the former conclusion; while Utica shale fossils found on both sides of the line of disturbance at the Normans kill indicate the presence of faunistic differences in the shales and sandstones, in spite of their apparent lithologic continuity.

The relation of the Normans kill, or Coenograptus, zone to the Utica shale is not expressly stated by the author, but it is clear that he places it near the top of the Utica shale. This follows from the following statement (p. 349): "Comparing the fauna, we find that the forms of the upper part alone of the Utica zone occur within the valley of the Hudson, and that the great graptolitic fauna of the Hudson valley is largely unknown in the

interior of the state. It is probable that the graptolitic fauna was prevented from spreading over the interior of the state by some such barrier as subsequently excluded the interior continental fauna of this period [Hudson river period] from the valley of the Hudson ". This combined with the statement that the upper or true Lorraine fauna has not been found to the east of Utica (p. 347), leaves only the faunas of the upper Utica and of the Frankfort shales to the Hudson river region. Thus according to Walcott the upper Utica is represented by the fauna discovered by Beecher near the old Dudley observatory, that of the Frankfort shales or of the lower division of the Lorraine formation is known from the shales of Waterford, and in the upper part of the former or the lower part of the latter the Normans kill fauna is to be placed.

In accordance with this conception of the divisions of the Hudson river shales and sandstones in the Hudson river valley, the term " Hudson " was proposed " for the series of shales between the Trenton limestone and the superjacent Upper Silurian rocks".

In the discussion following the reading of this paper Prof. Hall expressed his full concurrence with the results obtained by Mr Walcott.

H. M. Ami

It is an interesting fact that, as seen again from this paper, whenever the New York geologists had occasion to assign the Normans kill zone in the series of the New York rocks, they gave it a position within or above the Utica terrane, while the geologists who were studying the fauna of the same zone in Canada, Billings, Logan and Lapworth, invariably placed it below the Utica shale. This attitude of the two schools is still more emphasized by the next student of the graptolite faunas of Canada, Henry M. Ami (38).

Ami makes the following interesting remarks:

Before assigning a definite position to the rocks of Quebec city in the scale of terranes in America, it is necessary for the writer to state that so far he has been unable to find any evidence in the field, either stratigraphic or paleontologic, whereby the Hudson river rocks and Lorraine shales, as originally understood

by Emmons, could be correlated and referred to the same or an immediately following geologic terrane.

The fossils collected at Côte d' Abraham have a decided lower Trenton facies, as the presence of Solenopora compacta, or a variety of this species, seems clearly to indicate. From the long list of species obtained in the Montcalm market rocks [Normans kill fauna] it can readily be seen that we have there represented a fauna which has never yet been found either in the Lorraine, Utica or Trenton terranes—a fauna distinct from the faunas included in these three terranes whose characters are so well known throughout the continent in their undisturbed and complete development. It is the same fauna which has received in numerous places the name "Hudson river" e.g. at Normans kill and many other localities in New York and Vermont, and in Canada. Similar strata have also been observed in northern Maine, in Newfoundland and New Brunswick.

The apparently lower Trenton aspect of a portion of the Quebec *massif* as seen at Côte d' Abraham and Côte de la Négresse gives us an indication of the age of the strata at these points. Cut off on all sides by faults and separated from the Lévis rocks by the St Lawrence river, the Quebec terrane (which name I beg to propose for this series of strata such as we meet at the Montcalm market, Parliament square, and drill shed exposures) stands by itself in an anomalous position very similar to rocks of similar age which Prof. Lapworth designated as "unplaced in the series".

The presence of such forms as Agnostus, Aeglina, Ampyx, Dionide, Bathyurus, etc., points to a rather low[er] horizon than the Trenton, while I believe that it is perhaps premature to give the precise geologic position of the strata at Quebec, in the present light of our knowledge.

In the discussion which followed the reading of this important contribution to our knowledge of the Champlainic [Lower Siluric] terranes, Mr Walcott expressed the opinion, that, "if Mr Ami's determination of the fauna is correct, the horizon of the Quebec city rocks is that of the Trenton, probably the lower Trenton, and perhaps the upper portion of the Chazy of the New York section".

The writer concurs with Lapworth and Ami in considering the Normans kill or Marsouin zone as "a distinct development of the Ordovician", which view is supported by evidence obtained around Albany, and also with Walcott in so far as he considers the horizon of the Quebec city rocks as that of the lower Trenton.

In support of this view the writer desires to point out the following facts which can be derived from Ami's observations. The joint occurrence of a lower Trenton fauna with the Normans kill fauna in the Quebec massive suggests that the Normans kill fauna is either of lower Trenton age or directly preceded or succeeded that age. It is true that the presence of such genera as Agnostus, Aeglina, Bathyurus, Ampyx and Dionide, when considered in the light of their now known vertical range in America, is indicative of an older than Trenton age; but the writer has found east of Albany, at Rysedorph hill and Moordener kill, partly below the Normans kill shales, partly embedded in them, a conglomerate full of lower Trenton fossils, in matrix and pebbles, and mixed with numerous specimens of Ampyx and Remopleurides. And in Europe, notably in Sweden, the above mentioned genera ascend into and above horizons considered as homotaxial with the Normans kill and Utica shales. Agnostus and Ampyx occur in the Trinucleus shales of Sweden, Ampyx tetragonus even in the upper part of the middle graptolite shales; and Dionide is an important genus of the Trinucleus shales, where also Aeglina still occurs. Bathyurus is still well represented in the Trenton of America by forms like Bathyurus extans, spiniger and schucherti. The occurrence of these genera in the Quebec beds is, in the writer's opinion, an interesting proof of the European and Atlantic connections of the Normans kill fauna already indicated by the distribution of these graptolites which occur only in Europe and to the east of the Appalachian region, west of the Mississippi valley and in the far northwest, etc.; while the Trenton fauna has all the characters of an epicontinental fauna, restricted to the American continent and progressively developed by a sudden transgression of the sea. The retention of these ancient trilobite genera in the graptolite facies of the Trenton is then only an interesting instance of the retarded development of the oceanic fauna in contrast to the progressive development of the epicontinental faunas; relations which lately have been so well elucidated by Chamberlin (59) and Weller (60). These facial

and geographic relations of the Hudson river shales and Trenton limestone will be discussed more fully at a more opportune occasion.

R. R. Gurley

Dr R. R. Gurley has, after an exhaustive study of the North American graptolites, prepared a list of their vertical range (50) and, as a result of his investigations, concluded (p. 291) that "the vertical range of the American species represents a complete parallel to the range in other countries. This parallel is not a general one only, but is exceedingly detailed, extending beyond the genera down to the species, which in each horizon correspond to those of the equivalent European horizon almost without exception, although of course not every European species occurs in America, or vice versa". This inference stands in accord with Lapworth's conclusion of the parallelism of the graptolite faunas and supports his correlation of the Normans kill zone with the lower Trenton on the base of such parallelism. Dr Gurley also asserts the lower Trenton age of this zone, which he terms the Lower Dicellograptus zone.[1]

T. N. Dale

Shortly after the completion of the present paper a most elaborate account of the slate formation in the region to the northeast of the investigated territory, by T. Nelson Dale (63) came to hand. Mr Dale's views in regard to the age of the Hudson river beds agree in a gratifying manner with the results to which the writer was led by his own observations. In the slate belt, which extends northward from the Hoosac river in eastern New York and in Vermont for about 55 miles, the Cambrian slates are in some localities followed by Calciferous shales, with Calciferous graptolites and thin limestone beds, but in more localities they are overlaid by various other Champlainic [Lower Siluric] rocks which are described as Hudson grits, Hudson

[1]The upper Dicellograptus zone is Lapworth's zone without Coenograptus gracilis, in which, however, subsequently a Coenograptus has been found by Ami, and which has not yet been clearly differentiated in the Hudson river valley.

white beds, Hudson shales, Hudson red and green slates and Hudson thin quartzite. The Hudson grit (graywacke) is interbedded in many places with black shales or slates, which in a great number of localities furnished the typical Normans kill graptolite fauna (identified by R. R. Gurley). Many of these localities had been found by C. D. Walcott. These graptolite shales are not only closely connected with the Hudson grits, as the writer found them also to be at south Troy (Poesten kill, *see* p. 539) and near East Greenbush, but also with the green and red slates; for "at several points the Hudson grits appear to be replaced along the strike by the red and green Ordovician slate" (p. 189).

The Trenton limestone (p. 190) occurs only sporadically within the lower Siluric areas. "In some places it was probably deposited contemporaneously with the Hudson grits and shales, or it may underlie portions of them. In others it may represent the entire Lower Silurian series and should then be regarded as Trenton, Chazy and Calciferous."

This correlation of the Trenton limestone and the Hudson river beds is also expressed in the table of formations (p. 178), where it is said: "Trenton limestone: Limestone, occurring mostly west of the slate belt, replacing probably I (Hudson grits, red and green slate and graptolite shales), H (Hudson white beds and Hudson thin quartzite) and G (Hudson shales), and possibly F (Calciferous) and then representing the Trenton, Chazy and Calciferous."

RESULT OF FORMER INVESTIGATIONS

A brief retrospect of the opinions expressed by the various authors on the Normans kill fauna will show that there has been a decided trend in these opinions toward a correlation of the Normans kill zone with deeper and deeper terranes till now it oscillates, so to say, about the lower Trenton. This correlation is based entirely on paleontologic evidence and, as Dr Gurley's concise statement clearly shows, is hardly more than tentative. This, however, can not be surprising, when it is borne in mind, that all the graptolite beds in New York, notably those at Normans kill, the Abbey (Glenmont), Schodack Landing, Kinderhook and

Hudson, have, besides the graptolites, yielded only few other fossils, and none of decisive taxonomic value (*see* p. 569); that these graptolites are restricted to these beds; that, farther, these beds are hidden away in a huge mass of mostly barren shales and sandstones, and that, finally, this whole mass of rocks, which contains Trenton, Utica and Lorraine beds in similar lithologic development, is in New York as well as in Canada cut off from the neighboring terranes by extensive faults, thus apparently also frustrating all attempts at a stratigraphic solution of the problem.

DISCOVERY OF OUTCROPS (STATIONS) WITH FOSSILS

It is only in view of these extreme difficulties which besiege the Hudson river problem that the writer presents his observations on this problem in an area which appears insignificant in comparison with the great geographic extension of the beds in question. But only by restriction to a definite small territory has it been possible to visit every outcrop and, what is still more important, to collect in every outcrop most exhaustively and minutely. As a gratifying result of this method, there were found in the region described in the introduction, 29 localities which furnished fossils. These, with 7 localities known before, give 36 stations with fossils. These can be arranged according to their fossil contents in four zones, which, following the general strike of about n 20° e of the rocks in this part of the Hudson river valley, extend from n n e to s s w. The stations will be described according to these zones (*see* map).

DESCRIPTION OF STATIONS

A LORRAINE BEDS

Station 1. Cohoes falls of the Mohawk river

All along the lower Mohawk and specially from the high falls of the river at Cohoes to the islands in the Hudson river opposite the mouth of the Mohawk, is exposed an enormous mass of greatly contorted rocks (a sketch of these contortions is given by Mather, 4, pl. 2, fig. 1) of mostly shaly character; that is argil-

laceous and arenaceous shales with beds of argillaceous sandstone and gritty bands. These rocks have, in many places, become semi-metamorphic ("glazed shales" of the older New York geologists) by the influence of the orogenic forces. Fossils from them were known to Vanuxem, and the species reported by Hall (7) have been enumerated above (p. 493). Walcott remarks that this fauna connects the shales of the Hudson valley region with the Frankfort shale fauna of the central part of the state.

The writer had the good fortune to find an excellent opportunity for collecting in the usually very refractory shales by the opening of ditches for the purpose of laying water pipes in the southern part of Waterford. Here, at the end of Grace street, near the Mohawk, beds of dark argillaceous shales, changing through dark sandy shales into ferruginous sandstones, were cut into. They furnished:

Glyptocrinus decadactylus, *Hall*, numerous joints
Diplograptus putillus, *Hall*, several specimens[1]

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[1]This small form was originally described by Hall (11:44) from the "Hudson river group of Iowa", and is also cited by Schuchert from the "Hudson river group" near Granger and near Springvalley Minn., and from Graf Ia. One of Hall's types is reported in Whitfield & Hovey's catalogue (61) to have come from Dubuque Ia. According to Gurley's lists the form is restricted to the Utica horizon (lower Maquoketa shales). Sardeson (57) distinguishes the lower Maquoketa formation as "Diplograptus-bed". Though he does not give any identification of the Diplograptus, it becomes apparent from the localities of this horizon, mentioned by him (Graf Ia. and Granger Minn.) that Hall's and Schuchert's specimens were also obtained from this horizon. The writer's observations on the vertical range of this form in the east agree well with these data; for D. putillus has been found to be common in the Utica shale of certain parts of the Mohawk valley, specially north of Utica and near the village of Mohawk; and I have recently found it in great abundance, together with Orthograptus quadrimucronatus, Corynoides curtus and a minute, undescribed spinous Diplograptus, in the Utica shales directly above the Trenton limestone in the beautiful section along the shore of Lake Champlain near Panton Vt., to which interesting locality the writer's attention was kindly directed by Dr Theodore White of Columbia university.

The form may, however, as its occurrence at Waterford proves, pass into the Lorraine beds.

Diplograptus *sp.*, fragment of a larger mucronate (?) or macerated form, not well preserved

Corynoides *cf.* curtus, *Lapworth*[1]

Dalmanella testudinaria, *Dalman* sp.

cf. Orthis (?) centrilineata, *Hall*

Platystrophia biforata, *Schlotheim* sp.

Plectambonites sericea, *Sowerby* sp.

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[1]This little known graptolite has, hitherto, not been observed in America. Corynoides calicularis Nicholson, which occurs in the Scottish Hartfell and Glenkiln shales was recognized by Lapworth in the Canadian Dicellograptus zones and is the only species of Corynoides mentioned by him and Dr Gurley from America. It is also very common in the Normans kill shale, and was figured by Hall among the "germs", evidently on account of its similarity with the sicula (Decade 2, pl. B, fig. 19; 20th mus. rep't, pl. 1, fig. 19; Pal. N. Y., 3:508, fig. 7). While Corynoides calicularis is apparently restricted to the Dicellograptus zones, and did not continue to live into Utica time, another form, only half as long, much stouter and agreeing with the figure of Corynoides curtus, given by Lapworth (Armstrong, Young, and Robertson, Catalogue of West Scottish fossils. 1876. pl. 2, fig. 92) has been found to replace the longer form in the Utica beds of Panton Vt., the Rural cemetery of Albany and other localities in the Hudson valley, while specimens in the collection of the New York state museum prove its presence also in the Utica shale of Amsterdam. One slab from this locality is so densely covered with these graptolites that hardly any interspaces are left; on another slab from the same locality they lie associated with Diplograptus putillus, Lingula curta and Leptobolus insignis. One slab of typical black Utica shale from Sprakers Basin shows the same fossil. It is a remarkable circumstance that the writer has never seen a single specimen in the Utica shale of the middle or upper Mohawk valley, nor are there any specimens in the rich Rust collection of the state museum from Holland Patent. This may indicate a regional difference in the fauna of the Utica shale. The common occurrence of this fossil in the sandy shales of Waterford, whence the writer has it in the same slabs with Trinucleus concentricus and the lamellibranchs of that locality, proves that it even ascends into the Lorraine beds. One specimen has been found at Callanan's quarry near South Bethlehem in the shale of that formation 18 feet below the waterlime bed of the Upper Siluric.

The writer has obtained such a good representation of this still very imperfectly understood form (Frech cites it among the doubtful forms, 54: 580), that its more important morphologic characters can be made out, and will be published in another place.

Rafinesquina alternata, *Emmons* sp.
Modiolopsis anodontoides, *Conrad* sp.
M. nuculiformis, *Hall*
Cleidophorus planulatus, *Hall*
Lyrodesma poststriatum, *Emmons*
Archinacella patelliformis, *Hall* sp.
Conularia (Sphenothallus, *Hall*) sp.
Cameroceras proteiforme, *Hall* sp.
Lepidocoleus jamesi, *Hall and Whitfield* sp.
Triarthrus becki, *Green*
Trinucleus concentricus, *Eaton*

This fauna is undoubtedly, as determined by Hall, an eastern representative of the Lorraine fauna, or more exactly, as pointed out by Walcott, of the lower division of the Lorraine beds, viz, the Frankfort slates.

Station 2. Block island, Cohoes

Another typical Lorraine fauna was found a little farther northeast on Block island, a picturesque steep cliff rising from the rocky bed of the northern branch of the Mohawk below Cohoes. Along the eastern wall, besides graptolite shales with Diplograptus foliaceus and a few specimens of D. putillus, a stratum of fossiliferous mudstone is exposed over a considerable area. This furnished:

Heterocrinus heterodactylus, *Hall*. Stems and points, cc[1]
Sagenella *sp.* on Endoceras. r
Crania *sp.* r
Platystrophia biforata, *Schlotheim* sp. r
Cyrtolites ornatus, *Conrad*. c
Archinacella patelliformis, *Hall* sp. Smooth variety, c
Modiolopsis faba, *Hall*. c
Modiolopsis ? nuculiformis, *Hall*. c
Cleidophorus planulatus, *Hall*. cc
Lyrodesma poststriatum, *Emmons* sp. Lorraine form, c
L. pulchellum, *Hall*. c

[1] r=rare, rr=very rare, c=common, cc=very common.

Cameroceras proteiforme, *Hall* sp. r
Trinucleus concentricus, *Hall.* cc

Station 3. Dry creek, Watervliet

The writer has been unable to find another locality with as complete a fauna as this going southward in the strike of the beds of Cohoes. This is partly due to the lack of outcrops of these beds, caused by the general n ne-s sw strike of the Hudson river shales, which carries these Lorraine beds under the drift-covered plateau to the west of the Hudson river. Following the edge of the plateau about 3 miles to the southwest, a large outcrop is met with (station 3) along Dry creek, west of Green Island. This creek has formed a deep gorge through a homogeneous mass of soft gray argillaceous shales. In these beds only a single layer with fossils was found. There were a few specimens of Corynoides curtus and more abundant stipes of Diplograptus foliaceus. The writer colors station 3 (Dry creek) as a Lorraine station, as the two graptolites are of themselves noncommittal, while the beds by their extreme barrenness suggest their Lorraine age and also lie in the strike of the Cohoes rocks.

Station 4. South Cohoes

The reconstruction of a sidewalk in south Cohoes brought out a considerable mass of rock, which like that of Dry creek (station 3) consisted mostly of compact dark gray to black, argillaceous shales with very few specimens of Diplograptus foliaceus and Corynoides curtus.

Other outcrops of Lorraine beds

No outcrops of rocks which by their fossil contents could be attributed to the Lorraine age were found to the northwest and west of Albany, as the brooks have nowhere cut through the heavy drift covering to the bed rocks. This is specially observable along the northern affluents of the Normans kill. The next outcrops occur along the Vly, a southern tributary of the Normans kill, at the sawmill below Voorheesville, 7 miles west of

Albany, where alternating fine grained sandstone, conglomerate beds and gray fissile argillaceous and arenaceous shales occur. These rocks did not yield any fossils; but, as they are lithologically similar to the Lorraine beds of the Mohawk valley, dip regularly at 18° to n 80° w and are consequently outside of the region of disturbance of the Hudson river valley and probably continuous with the Lorraine beds of the Mohawk valley, they can with a sufficient degree of certainty be correlated with these beds. Furthermore, Utica shale fossils (*see below* station 21) were found in underlying rocks farther down the creek. Similar shining gray fissile shales were found on the south bank of the Normans kill about a mile above (west) the mouth of the Vly; and an excellent exposure of Lorraine beds was met at French mills, 11 miles west of Albany, where gray sandstone banks, 10 feet and more in thickness with intercalated shales, cross the river.

South of this neighborhood, at the Indian Ladder, the Lorraine beds underlie the Manlius limestone, and yielded Dalmanella testudinaria and Trinucleus concentricus, as reported by Walcott. Other outcrops of Lorraine beds can be observed at several places along the foot of the Helderberg mountains. One of the best of these is that along Sprayt kill at South Bethlehem, where, below the railroad bridge, some 20 feet of sandstone causes a waterfall and farther up, at Callanan's road metal quarry, the contact with the Upper Siluric Waterlime is exposed. Numerous sandstone banks alternate here with light colored, soft, argillaceous shale and some bands of more sandy shale. In the shale, 18 feet below the Waterlime, a Corynoides was found. These beds dip slightly southwest. A very coarse sandstone with bluish green mud pebbles is exposed 4½ miles farther south close below the Waterlime and Manlius limestone along the road leading from Ravena to Aquetuck. It strikes n 60° e and dips 40°, n 150° e, is hence, again involved in the tilting to the east, characteristic of the Hudson valley region. It is doubtful whether this sandstone still belongs to the Lorraine rocks or is already the sandy development of a deeper terrane. Its strike would carry it far to the east of the Lorraine

zone, and it is possible that it is continuous with similar beds of lower Trenton age exposed along the lower Vlaumans kill. Unfortunately no outcrops could be found along the middle and upper courses of the Coeymans and Vlaumans kills.

No other exposures of Lorraine beds have been found in the investigated area. Their distribution to the northwest, west and southwest of Albany is evidence of the restriction of the Lorraine beds to the western part of the area.

Prof. Prosser has lately separated the Utica and Lorraine shales of the lower Mohawk valley by testing them with HCl, with which reagent the calcareous Utica shale will strongly effervesce, while the Lorraine shale does not react. This test had not suggested itself to the writer when in the field; but, on later application to the shales of the various terranes of the Hudson valley region near Albany, it was found to fail in the clastic rocks of this region, where even the Trenton is represented by argillaceous shales, and among the Utica shales only those from the penitentiary at Albany were found to effervesce, while all specimens of Utica shale from various localities of the Mohawk valley subjected to this test by the writer have strongly reacted. This indicates the great change in the marine conditions from west to east in this region throughout a long period.

B UTICA BEDS

East of this area of Lorraine rocks, the presence of a zone of Utica shale extending in the direction of the general strike of the shales of the Hudson river valley, has been established by the finding of 15 outcrops which contain Utica shale fossils (Compare the accompanying map).

Station 5. Mechanicsville

The excavation of a large spillway for the establishment of the Hudson light and power company of Mechanicsville, on the Hudson, about 2 miles below Mechanicsville, offered a rare opportunity for collecting in the shale. Though this locality lies several miles north of the boundary of the area investigated thus far, it was thought expedient to include its description in this paper, as the

fauna was found to contain some valuable additions to the list of Trenton and Lorraine fossils observed in the Utica beds of this region, and besides, indicates the presence of the upper Dicellograptus zone, which hitherto has not been observed south of the St Lawrence region, in eastern New York. The fossils collected are:

Sponge. r
Corynoides curtus, *Lapworth.* cc
Diplograptus quadrimucronatus, *Hall.* cc
D. foliaceus, *Murchison* sp. c
Climacograptus caudatus, *Lapworth.* c
Dawsonia campanulata, *Nicholson.* c
Pontobdellopsis cometa *sp. n.*[1]
Lingula curta, *Conrad.* c
Leptobolus insignis, *Hall.* c
Schizocrania filosa, *Hall.* r
Pholidops subtruncata, *Hall.* c
Plectambonites plicatella, *Ulrich.* cc
P. sericea, *Sowerby* sp. c
Cyclospira bisulcata, *Emmons* sp. c
Archinacella patelliformis, *Hall* sp. cc
Protowarthia cancellata, *Hall* sp. (=Bellerophon bilobatus, *Hall*) r
Cyrtoceras annulatum, *Hall.* rr
Modiolopsis modiolaris, *Conrad.* r
M. ? nuculiformis, *Hall.* r
Goniophora carinata, *Hall* sp. c
Cuneamya, *sp.* fragment. r
Ctenodonta levata, *Hall.* r
Conularia trentonensis, *Hall.* c[2]

[1]*See* p. 574.

[2]A comparison of this form with the type species of Conularia trentonensis, Hall, preserved in the New York state museum, and with typical material of Conularia hudsonia, Emmons, from the Lorraine beds, proved that the Utica form, instead of approaching the Lorraine species by greater coarseness of its sculpture, has, if any different sculpture, a rather closer and finer arrangement of the transversal and longitudinal lines than even the Trenton form.

Aparchites minutissimus, *Hall.* c
Ctenobolbina ciliata, *Emmons* sp. c
Lepidocoleus jamesi, *Hall & Whitfield* sp. cc[1]
Turrilepas (?) filosus *sp. n.* r[2]
Pollicipes siluricus *sp. n.* r
Calymmene *sp.* small pygidia. r
Trinucleus concentricus, *Hall.* cc
Triarthrus becki, *Green* sp. cc

While this fauna by its most common fossils, Corynoides curtus, Diplograptus quadrimucronatus, and Triarthrus becki, which cover whole surfaces, and by the presence of Leptobolus insignis and Lingula curta is characterized as being of Utica age, it contains a considerable number of Trenton as well as of Lorraine forms. The Trenton forms are:

Climacograptus caudatus, Cyclospira bisulcata, Cyrtoceras annulatum, Goniophora carinata, Ctenodonta levata, and Conularia trentonensis.

The Lorraine forms are: Pholidops subtruncata, Plectambonites plicatella, Modiolopsis modiolaris, Aparchites minutissimus, Ctenobolbina ciliata.

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[1]The vertical range of this minute but pretty fossil cirriped is worthy of special notice. It was originally described by Hall and Whitfield (Paleontology of Ohio. 1875. 2:106) from the Hudson river group, Cincinnati O., the authors stating however, at the same time, that they had received from C. D. Walcott "specimens apparently identical on surfaces of Trenton limestone from near Trenton Falls N. Y." This statement can be verified by the writer, who collected in the Rafinesquina deltoidea beds of Trenton Falls a well preserved specimen. The collections from the shales of the Hudson valley prove now that it also occurs and is even most abundant in different horizons of the Utica terrane; for it has been found besides in the Lorraine beds of Waterford (station 1), in the upper Utica beds of Green Island (station 10) and of the Dudley observatory (Dr Beecher), in the lower Utica beds of Mechanicsville (station 5) in great profusion, and in the middle Trenton shales of Port Schuyler (station 23). It therefore persisted, at least in this region, from the middle Trenton into the Lorraine.

[2]*See* descriptions of this and the next species p. 577.

Of these however, Pholidops subtruncata, Modiolopsis modiolaris and Aparchites minutissimus present varietal differences. Pholidops subtruncata does not possess the faint median angulation of the Lorraine form, and has besides, been found in the Canadian Trenton by Ami; Modiolopsis modiolaris has the back and base nearly parallel and thus approaches Ulrich's M. subrecta, or is identical with one of the Utica varieties, mentioned by this author; and also the Aparchites minutissimus approaches the Trenton variety by the absence of the subcentral projecting point.

The Lorraine element is, hence, by no means, so strongly represented in this Utica fauna of Mechanicsville as appears at first glance or as it is in the Utica shales of Green Island. This is still more emphasized by the absence of Cleidophorus planulatus, Cyrtolites ornatus and Lyrodesma pulchellum, while, on the other hand, the Trenton element is so strong that the beds almost assume the character of transitional beds between the Trenton and Utica terranes.

An important and novel factor in this fauna is the peculiar Climacograptus caudatus which occurs frequently and in large specimens. This striking type of graptolite structure was first described by Lapworth from the Hartfell shales of Scotland which are considered homotaxial with the upper Dicellograptus zone of Canada, from which the same graptolite has been reported. As it is restricted to the upper Dicellograptus zone, and, therefore, is a valuable index fossil, its occurrence in the lowest Utica shale of Mechanicsville is of significance, indicating the presence of this zone in the Hudson river region and its proximity to the lowest Utica. If we add, that also Dawsonia campanulata, found at Mechanicsville, and Cryptograptus tricornis, found in similar lower Utica beds on Van Schaick island (*see* station 8) are fossils of the Dicellograptus zones, and not of the Utica horizon, it can be concluded with some degree of certainty that the upper Dicellograptus zone, when present in the Hudson river valley, directly underlies the Utica terrane, that is, is homotaxial with the whole or part of the

upper Trenton. Unfortunately, no fossils have been found yet in this neighborhood between the middle Trenton Diplograptus amplexicaulis beds (*see* stations 22-27) or the lower Dicellograptus beds of Lansingburg and the Utica belt farther west.

Station 6. Laveny's point, Waterford

This locality is a small bluff on the west bank of the Hudson, a little north of the bridge connecting Waterford and Lansingburg. Here are exposed steeply east dipping (50°, n 110° e) intensely black, hard, indurated, argillaceous slates, overlain a little farther north by gray arenaceous and micaceous shales, which in turn underlie alternating sandstones and shales. The black slate was found to contain:

Climacograptus typicalis, *Hall*[1]
Diplograptus putillus, *Hall*
D. spinulosus *sp. n.* (a colony and numerous hydrorhabds)
Endoceras proteiforme, *Hall*

Climacograptus typicalis and Diplograptus spinulosus are restricted to the Utica shale, while Diplograptus putillus finds its principal development in that terrane.

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[1]Climacograptus typicalis is, according to the consensus of all writers on the Utica and Normans kill faunas, restricted to the Utica shale and does not occur in the latter fauna. The only exception is found in Frech's statement (54:612) that he has seen specimens of this form from Normans kill in the Breslau museum. Frech, however, also considers Cl. parvus a dwarf form of Cl. typicalis, basing this opinion on a specimen from Cincinnati in the same museum. As Cl. parvus does not occur at Cincinnati, but is restricted to the Normans kill beds, where it is one of the most common forms, and as a comparison of these two graptolites, which nowhere occur together, shows that they can not be identical, it is probable that he did not recognize the two forms, and his Cl. typicalis from Normans kill is only a somewhat larger specimen of Cl. parvus.

Frech also proposes to change Hall's adjective, "typicalis" to "typicus" on the ground that the former is an anglicism. While it is true that typicalis is not a word of classic Latin origin, it was of common usage in later Latin, and, as many very expressive words have been taken from the post-classic Latin, it would not be practical to deprive the paleontologic nomenclature of this source of words by too strict philology.

Station 7. Peoble's island, Waterford

In a similar black slate on Peoble's island (station 7), in the Hudson river opposite Waterford and about 2 miles southwest of Laveny's point, were found:

Climacograptus typicalis, *Hall*

Leptobolus insignis, *Hall*

Station 8. Van Schaick island

This large island lies directly south of Peoble's island and forms a part of the city of Cohoes. The construction of a sewer system provided here a good opportunity of collecting in the compact, black, carbonaceous shales of the northern part of the island. The shale contains:

Diplograptus foliaceus, *Murchison* sp. cc

D. putillus, *Hall.* r

Cryptograptus tricornis, *Carruthers* (=Diplograptus marcidus, *Hall*) r

Cameroceras proteiforme, *Hall* sp. r

Leptobolus insignis, *Hall.* r

Schizocrania filosa, *Hall.* r

While the general character of the rock and fauna is distinctly that of Utica beds, the occurrence of Cryptograptus tricornis is wholly unexpected and difficult of explanation, as this graptolite thus far has been, in America, observed only as a member of the upper and lower Dicellograptus faunas, and in Scotland is restricted to the Glenkiln shales, which are homotaxial with the Normans kill or lower Dicellograptus shales. The presence of this graptolite points evidently to a position of these beds at the base of the Utica horizon.

Station 9. North shore of Green Island

In the bluff along the northern shore of Green Island, directly west of the railroad bridge, several fossil-bearing bands were found in the shales. Two of these were calcareous, and consisted almost entirely of valves of brachiopods, a third was a black compact mudstone, which in one place was highly charged with fossils. The fossils collected were:

Pholidops subtruncata, *Hall.* r

Dalmanella testudinaria, *Dalman* sp. cc

Plectorthis plicatella *Hall.* c

Plectambonites sericea, *Sowerby* sp. var. aspera, *James*[1]

Rafinesquina alternata, *Emmons* sp. cc

Parastrophia hemiplicata, *Hall.* c

Pleurotomaria *cf.* lenticularis, *Hall.* r

Murchisonia (Lophospira) uniangulata *var.* abbreviata, *Hall.* c

Cyclonema bilix, *Conrad*, sp. r

Archinacella patelliformis, *Hall* sp. cc

Protowarthia cancellata, *Hall*, sp. (=Bellerophon bilobatus, *Hall*) c

Cyrtolites ornatus, *Conrad.* r

Clionychia undata, *Emmons* sp. c

Technophorus cancellatus *sp. n.* c

Cleidophorous planulatus, *Hall.* cc

Lyrodesma poststriatum, *Emmons* sp. r

L. pulchellum, *Hall.* c

Orthoceras tenuitextum, *Hall* sp. r

O. lineolatum, *Hall* sp. r

Spyroceras bilineatum, *Hall* sp. c

Isotelus gigas, *De Kay.* c

Calymmene senaria, *Conrad.* r

Pterygometopus callicephalus, *Hall.* cc

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[1]This variety is marked by acute, oblique wrinkles along the cardinal line, such as occur in Strophomena rugosa var. subtenta, and Strophomena incurvata (= S. filitexta). This feature is constant in the vast numbers of valves which compose some of the pebbles in the conglomerate of Rysedorph hill (*see* p. 546) and Moordener kill, and it continues upward into the Utica shale of Green Island, and Menands, though in these localities forms with and without wrinkles occur together. The same variety was observed by Dr Beecher in the material from the Dudley observatory, and listed as Leptaena subtenta ?. The wrinkling is apparently rare among specimens collected west of the Hudson river region, for it is not mentioned in the very detailed accounts of the characters of this species in the west by Sardeson, Winchell and Schuchert, but it was listed among the Cincinnati fossils by James as Leptaena aspera and has been figured by Hall and Whitfield. (Geol. sur. Ohio. Paleontology. v.1. pl. 5. fig. 3 f.)

Trinucleus concentricus, *Hall.* cc
Ceratocephala (Acidaspis) trentonensis, *Hall.* rr
Lepidocoleus jamesi, *Hall & Whitfield* sp. r
Pollicipes siluricus *sp. n.* c

Station 10. East shore of Green Island

Nearly the same fauna was found in dark gray, fissile argillaceous shales, outcropping at the water edge along the east shore of Green Island a quarter of a mile below the state dam. The fauna of these shales consists of:

Diplograptus foliaceus, *Murchison.* r
Climacograptus typicalis, *Hall.* r
Corynoides curtus, *Nicholson.* r
Pholidops subtruncata, *Hall.* r
Dalmanella testudinaria, *Dalman* sp. cc
Plectorthis plicatella, *Hall.* c
Plectambonites sericea, *Sowerby* sp. cc
Rafinesquina alternata, *Emmons* sp. c
Murchisonia (Lophospira) uniangulata *var.* abbreviata, *Hall.* r
Lophospira bicincta, *Hall* sp. r
Archinacella patelliformis, *Hall* sp. c
Clionychia *sp. n.* rr.
Cleidophorus planulatus, *Hall.* cc
Modiolopsis faba, *Hall.* c
Cameroceras proteiforme, *Hall.* r
Triarthus becki, *Green* sp. r
Calymmene senaria, *Conrad.* r
Cyphaspis *sp.* rr
Trinucleus concentricus, *Hall.* cc
Ctenobolbina ciliata, *Emmons* sp. c
C. ciliata *var.* conuta *var. n.* c
Lepidocoleus jamesi, *Hall & Whitfield* sp. r

A comparison of these two faunas from Green Island with that discovered by Dr Beecher near the Dudley observatory at Albany proves their identity. Dr Beecher considered this fauna as being

of Utica age, and Walcott declared it to represent in the whole the upper Utica age of the Mohawk valley region. It is remarkable for the considerable number of Lorraine forms on one hand and the nearly as great number of Trenton forms on the other. Some of these Lorraine forms were also observed in the very old Utica beds of Mechanicsville, and their varietal differences from the typical Lorraine forms remarked on. None of these Trenton forms occur in the pure Lorraine faunas of Block island and Waterford.[1]

Station 11. Railroad station, Menands

A few fossils were discovered by Dr Clarke in fissile argillaceous shales exposed in a small gravel pit about a hundred yards north of Menands station. The fossils are:

Dalmanella testudinaria, *Dalman* sp. cc
Plectorthis plicatella, *Hall.* c
Plectambonites sericea, *Sowerby* sp. cc
P. sericea *var.* aspera, *James* var. c
Rafinesquina deltoidea, *Conrad* sp. rr
Archinacella patelliformis, *Hall.* c
Bellerophon bilobatus, *Hall.* r
Spyroceras bilineatum, *Hall.* r
Ctenobolbina ciliata, *Emmons* sp. r

The presence of Plectorthis plicatella and Spyroceras bilineatum connects this faunule with the faunas of Green Island.

Station 12. Devil's Den, Watervliet

In a deep gorge, called Devil's Den (station 12), behind Gen. Schuyler's historic home and half a mile west of Watervliet, blackish and gray, fissile, soft argillaceous shales, somewhat sandy toward the upper end of the gorge, are exposed for about half a mile. These yielded a number of well preserved specimens of Orthograptus quadrimucronatus, Hall sp.

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[1]The association of Trenton and Lorraine forms in the same beds, and the peculiar position of these beds in the Utica zone will be discussed later (p. 564).

Station 13. Buttermilk fall, Watervliet

At the so-called Buttermilk fall (station 13) just south of the Devil's Den, Diplograptus putillus, Hall was found in black shales.

Station 14. Rural cemetery, Albany

One mile directly south of the last two localities lies the Rural cemetery of Albany (station 14). Here a rich fauna was discovered by Dr Clarke in a road metal quarry close to Prof. James Hall's grave. The rock is a deep black, strongly carbonaceous, argillaceous shale. It contains:

Orthograptus quadrimucronatus, *Hall* sp. in great profusion and exquisite preservation, in fact in the best state of preservation of rhabdosomes of graptolites ever seen by the writer in shale.

Diplograptus putillus, *Hall*

D. spinulosus *sp. n.*

Corynoides curtus, *Lapworth*

Dendrograptus *sp.*[1]

[1]There occur in the shale of the Rural cemetery extremely fine and slender, chitinous, irregular branching threads of undoubted graptolitic nature. These are rolled up, the larger and smaller branches separately, into an intricate, irregularly convolute mass. Such a form has been described and figured by Emmons American geology. 1875. pt 2. p. 109. pl. 1. fig. 7) as Nemagrapsus capillaris. Hall did not recognize the genus, as one of Emmons's species, N. elegans, is only a fragment of Coenograptus gracilis, and the relations of the other form, N. capillaris, on which neither thecae nor thecal apertures were observed, "can scarcely be determined from the figures given" (11:43; 13:211). The genus was later accepted by Lapworth, but Roemer (54:587) remarks that Hall, having access to the material, was certainly better prepared to judge its value. Ami (Bul. geol. soc. Amer. 1891. II. table p. 495) reports it doubtfully from the Canadian Calciferous; and Gurley, after having described a form as belonging to Nemagraptus which he later recognized to be a Thamnograptus, declares that he has found typical specimens of Nemagraptus capillaris at Stockport, Columbia co., but does not describe them (50:306), The writer's material shows all the features indicated by Emmons's figure. Both the figure mentioned and the material suggest that the fossils consist of the broken terminal filiform branches of some delicate ramose graptolite which, drifting about, were rolled up. A comparison with specimens of Dendrograptus tenuiramosus, Walcott (19:21. pl. 1. fig. 4) from the Utica shale shows that our form on the

Eopolychaetus albaniensis *sp. n.*
Pontobdellopsis cometa *sp. n.*[1]
Leptobolus insignis, *Hall*
Schizambon (?) fissus *var.* canadensis *Ami*
Hormotoma *cf.* gracilis, *Hall* sp.

With the exception of Dendrograptus, which at this locality is of rare occurrence, all graptolites of this fauna were found in the lowest Utica shale at Panton Vt. As the same combination of graptolites has also been observed on slabs from the neighborhood of Amsterdam N. Y., it seems to constitute a faunule characteristic of a certain horizon of the Utica shale in New York, evidently of the lower part of the formation. In all three localities the graptolites are rarely found mixed but occur on different surfaces of closely adjoining layers; only the rarer D. spinulosus mingling with the others, as if they were assorted according to their weight while drifting about. The other graptolites of the Utica shale occur for the most part separately in the shales of the Mohawk valley; this is specially notable of Climacograptus typicalis, Cl. bicornis and Diplograptus ruedemanni.

Station 15. Old Dudley observatory, Albany

3 miles S SW of the Rural cemetery exposure and just north of Albany, on Patroon's creek near the old Dudley observatory (station 15) is the exposure from where Dr Beecher, in 1889, obtained the first unmistakable Utica fauna from the Hudson river shales (*see* p. 502).

whole is more slender and flexible (only .1 mm wide), but its thickest basal parts correspond in thickness to the terminal parts of that extremely delicate graptolite whose thin filiform ends also show at times an inclination to become convolute. Furthermore most of the branches possess the same smooth, unindented character and apparently, though not distinct enough to permit positive assertion, small pits along the median line. In the absence of more complete material, it seems therefore justifiable to consider this fossil as consisting of the broken, thin filiform ends of Dendrograptus tenuiramosus or a similar species.

[1]*See* description of these fossils p. 574.

Station 16. Penitentiary, Albany

At the opposite outskirts of Albany, 2 miles to the southwest of the locality just mentioned, a graptolite fauna was discovered by Dr Clarke near the penitentiary (station 16) in a soft, black shale of the appearance of typical Utica shale and which also effervesces with HCl. The fauna consists of:

Corynoides curtus, *Lapworth*
Orthograptus quadrimucronatus, *Hall* sp.
Diplograptus putillus, *Hall*
D. spinulosus *sp. n.*
Climacograptus typicalis, *Hall*
Leptobolus insignis, *Hall*
Undetermined brachiopod

The first is the most common graptolite; it entirely covers some slabs.

Station 17. Beaver park

J. Van Deloo collected, some years ago, at the time of the laying out of Beaver park, a few graptolites in a ravine in the northern part of the park. These on investigation proved to be specimens of Diplograptus putillus, Hall, indicating the Utica age of the beds of this locality, which is only a short distance east of the preceding locality.

Station 18. Normansville

2 miles farther southwest, along the general strike of the rocks, is Normansville on the Normans kill. While at Normansville itself, in the sandstones and shales exposed above and below the bridge, no fossils were found, and the age of these rocks remains in doubt, a small outcrop of shale about a mile farther up, 100 yards below the landing of the picnic ground on the right bank of the river, furnishes graptolites (station 18). The rock is a deep bluish black, thick bedded argillite with conchoidal fracture and iron-stained cleavage planes. It is filled with specimens of

Climacograptus bicornis, *Hall*

Besides this occur:

Diplograptus quadrimucronatus, *Hall*

Diplograptus *cf.* foliaceus, *Murchison*, fragments

Corynoides curtus, *Lapworth*

Leptobolus insignis, *Hall*

Station 19. Ravine by Normans kill

About half a mile farther up the river in a ravine in the south bank a gray, arenaceous and micaceous, thin bedded shale was found which yielded quite a number of specimens of Diplograptus putillus, Hall (station 19). The beds of this, as those of all preceding stations, dip steeply to the east and have been involved in the tilting of the Hudson river beds.

Station 20. Black creek, Voorheesville

Following the Normans kill no outcrops are found in its widening valley or along any of the tributaries till reaching Black creek, a small southerly affluent, 4 miles farther up (station 20). The banks and the bed of this creek are formed of dark, often black, soft, non-metamorphic, mostly argillaceous shales, from which the creek derives its name. While near its mouth the shale is slightly disturbed by a fault which, according to its southwest strike, still belongs, as an accessory fault, to the Hudson river system of faults, the shales farther up the creek show a regular n 70° w dip and n 160° w strike, and lie hence outside the easterly tilted block of the Hudson river region. The large fault reported by Emmons and Ford as extending from Saratoga Springs across the Mohawk river and separating the tilted and folded Hudson river region from the undisturbed region to the west, probably passes the Normans kill between the last two stations and may also account for the lack of outcrops and the broadening of the valley between them. These black shales contain:

Orthograptus quadrimucronatus, *Hall* sp.

Diplograptus putillus, *Hall*

Climacograptus typicalis, *Hall*

Sagenella ambigua, *Walcott*
Cameroceras proteiforme, *Hall* sp.
Triarthrus becki, *Green*

They are hence undoubtedly of Utica age.

Station 21. The Vly, Voorheesville

The next southerly tributary of the Normans kill is the Vly. This creek forms, as above noted, a fall below Voorheesville, caused by a heavy bank of sandstone which suggests the Lorraine age of these beds. Following the course of the creek downward, argillaceous shales, sandy shales and sandstone beds are passed in manifold alternations. They show a general western dip (20°), and in two places are thrown into a series of small parallel folds, a few feet wide, striking n 15° e. These as well as a fault, which runs in the same direction, are evidently the faint westerly outrunners of the powerful Appalachian disturbances of the Taconic mountains and of the Hudson river valley region with which they run parallel.

Farther down, about halfway between the sawmill and the mouth of the creek, black shales begin to replace the sandstones and lighter colored shales. In one of the lower drab beds of sandstone numerous large specimens of Climacograptus typicalis were found, indicating the Utica age of these lower sand beds (station 21). This sandstone effervesces with HCl and is, hence, calcareous, like the Utica shale of the Mohawk valley. In the dark gray sandy shales below this sandstone, which, however, do not effervesce, were found:

Climacograptus typicalis, *Hall*
Sagenella ambigua, *Walcott*
Cameroceras proteiforme, *Hall* sp.

It thus appears that along the Vly a section is exposed from the Utica shale into the overlying Lorraine beds. This outcrop of Utica shale is the most southern and western which could be found in the region studied, as this shale toward the Helderberg mountains dips under the Lorraine beds, which in their turn

are overlain by the Upper Siluric and Devonic strata of these mountains.

Extension of zone of Utica shale

The stations 5 to 21 comprise all the localities with Utica fossils known to the writer in this region. They are arranged, as a glance at the map will show, in a zone which, beginning at the banks of the Hudson river at Laveny's point, passing over the islands at the mouth of the Mohawk and following thence the edge of the plateau to the west of the Hudson valley, crosses the upper part of the city of Albany and extends to the Normans kill, where it passes under the drift. As this series of outcrops lies in the general direction of the strike of the rocks, and the latter form a mass with uniform easterly dip, it may be safely concluded that this zone represents a continuous terrane of Utica beds overlying the Lorraine beds of equal dip in the tilted region, and underlying the latter in the undisturbed region to the west of the separating fault. Toward the north the zone probably connects with the Utica shale known from the neighborhood of Mechancisville, Saratoga Springs, Sandyhill, etc.

C MIDDLE TRENTON BEDS

Station 22. Watervliet arsenal

The next group of stations (stations 22-26) comprises five localities which may be arranged in two rows extending from n ne to s sw on both sides of the Hudson river south of Watervliet and Troy. These localities furnish Trenton fossils. The occurrence of the latter was first made known by Whitfield (see p. 496), who reported the finding of Diplograptus amplexicaulis at the Watervliet arsenal (station 22), and south of Troy in shaly partings between layers of metamorphic limestone. The locality at the arsenal is no more accessible, but part of the material collected at that time is preserved in the state museum. It consists of very soft bluish black, argillaceous shale, which does not effervesce with HCl and is thickly packed with a long, narrow graptolite which in dimensions, arrangement and form of thecae

corresponds with the Middleville specimens of Diplograptus amplexicaulis[1] with which it was compared.

Station 23. Fitzgerald's quarry, Port Schuyler

In James Fitzgerald's quarry (station 23) ¾ of a mile south of the arsenal, at the western terminus of Fourth street in Port Schuyler, thick bedded gray and black argillaceous shales and arenaceous, mica-bearing argillite are broken for road metal. The sandy beds contained:

Schizocrinus nodosus, *Hall*
Dalmanella testudinaria, *Emmons* sp.
Plectorthis plicatella, *Hall*
Platystrophia biforata, *Schlotheim* sp.
Plectambonites sericea, *Sowerby* sp.
Rafinesquina alternata, *Conrad* sp.

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[1]Diplogaptus amplexicaulis was first described by Hall from the middle Trenton of Trenton Falls and Middleville. There, as well as at Trenton, it occurs in great profusion in certain beds of the middle Trenton, while in the Rathbone brook section, south of Trenton Falls, it was also observed in beds considered as lower Trenton by Dr Th. A. White (51:86). Whitfield, as observed (p. 496) found it at the Watervliet arsenal and at south Troy, and based on it his correlation of these shales with the Trenton. Gurley, who considers it as only a mutation of D. foliaceus, assigns it to the Chazy (Mystic, Can.) and Trenton. Joseph F. James records its collection in the typical Maquoketa locality (Amer. geol. 4:237); Walcott mentions its being found in the upper part of the Lorraine section (36a:339); and Whitfield enumerates in his catalogue (61:20–21) as D. amplexicaulis a number of Hall's types of Gr. pristis of *Pal. N. Y.*, v. 1, from Turin, Lorraine, Collinsville and the Oxtungo creek. It becomes apparent from these citations that this graptolite is of rather uncertain value as an index fossil of the Trenton; it has been reported from beds ranging from the Chazy to the Lorraine, and probably the form is not yet well understood or D. foliaceus, to which it is closely related, has been mistaken for it. The amplexicaulity of the thecae is not restricted to this species, the concavo-convex section of the rhabdosome is not observable in flattened specimens, so that in the determination of specimens from the shale one is restricted to the observation of the dimensions, outline of thecae and rhabdosome, and of the general habit. These characters, however, being subject to alteration by variations in pressure, are often difficult of exact observation. The relations of this form to D. foliaceus and its vertical range apparently need farther study. The writer has not seen typical specimens of this form from beds of younger than middle Trenton age.

Ctenobolbina subrotunda *sp. n.*

Lepidocoleus jamesi, *Hall & Whitfield* sp.

In the more argillaceous rock were found:

Diplograptus (Glyptograptus) amplexicaulis *Hall*

D. foliaceus, *Murchison*

Proëtus *cf.* parviusculus, *Hall*

The combination of Diplograptus amplexicaulis with Schizocrinus nodosus and Proëtus cf. parviusculus is fairly sufficient evidence of the Trenton age of the shales and sandstones in Fitzgerald's quarry; for D. amplexicaulis occurs typically in the lower and middle Trenton and Schizocrinus nodosus and Proëtus parviusculus (*see* next station) are known from the Trenton only. Ctenobolbina subrotunda is nearest related to the Trenton species (Ct. fulcrata and Ct. crassa, Ulrich) of that genus (*see* description, p. 576).

Station 24. Brothers's quarry, south Troy

The outcrop south of Troy where Whitfield 26 years ago collected the Trenton graptolite, could not be precisely located; at least no information of the former occurrence of limestone in that neighborhood could be obtained. There were, however, several localities found which furnished ample evidence of the presence of Trenton fossils and which, as they contain calcareous sandstone banks with intercalated impure limestone banks and shales, may be identical with Mr Whitfield's collecting ground.

The most important locality is the Brothers's or Lavery's quarry station 24), at the brow of the hills east of south Troy. Diplograptus amplexicaulis is found here in great numbers in black, argillaceous shale at the east side of the quarry and more sparingly in association with Corynoides calicularis in similar beds at the opposite side of the quarry.

In calcareous sandstone beds which contain dark impure limestone banks consisting of brachiopod shells, in the middle part of the quarry, occur brachiopods, a number of which were first collected by Gilbert Van Ingen of Columbia university and kindly left with the writer; and one bed is filled with bryozoans. The beds yielded:

Schizocrinus nodosus, *Hall*
Pachydictya acuta, *Hall* sp.
cf. Escharopora angularis, *Ulrich*
Prasopora *sp.*
Dalmanella testudinaria, *Dalman* sp.
Plectorthis plicatella, *Hall*
Platystrophia biforata, *Schlotheim* sp.
Plectambonites sericea, *Sowerby* sp.
Rafinesquina alternata, *Emmons* sp.
Rhynchotrema increbescens, *Hall* sp. (= inaequivalvis, *Castelnau* sp.)
Proëtus parviusculus, *Hall*

Of these species Schizocrinus nodosus indicates the Trenton age in general, while Pachydictya acuta is reported by Hall (7: 75) as "of frequent occurrence in both the lower and central portions of the Trenton limestone", a statement with which Winchell and Ulrich concur in reporting the fossil from the Clitambonites, Fusispira and Nematopora beds of Minnesota (49: 111). Escharopora is, according to the same authors, restricted to the Stones river, Black river, lower and central Trenton beds. Rhynchotrema increbescens, in the restricted meaning (i. e. with the exclusion of the distinct Lorraine form, R. capax, originally included by Hall in this species) is a Trenton form. In the west it occurs in the upper Black river group, lower and middle Trenton (49: cxv) and in Canada it is found in Black river and lower Trenton. It is, hence, indicative of the lower or middle Trenton age of the Troy beds. Proëtus parviusculus was originally described by Hall (14: 223) as occurring "in shales of the Hudson river group, Cincinnati, Ohio". The correlation of these shales has, however, changed since that time; for Winchell and Ulrich cite the form from the Trenton of the Cincinnati region. Dr Clarke (49: 754) reports it from the base of the Galena shales at St Paul (Clitambonites bed, Winchell and Ulrich, which is lower Trenton). In Canada it has also been found in the Trenton.

The occurrence of Pachydictya acuta, Rhynchotrema increbescens and Proëtus parviusculus would, hence, indicate a lower or middle Trenton age for these beds, which correlation can, on account of the abundance and association of Diplograptus amplexicaulis, with these fossils, be limited with a fair degree of exactness to the middle Trenton age.

A remarkable and easily misleading feature of some beds in this as well as in the Fitzgerald quarry is their great similarity to some Lorraine beds at Waterford; for in all three localities there occur gray, sandy argillaceous rocks with iron-stained fossils, which it would be difficult to separate by their lithologic aspect, but the fossil contents and a strong admixture of calcareous matter in the rocks of the Brothers's quarry show that this similarity is only accidental.

Station 25. Ruscher's quarry, south Troy

Directly south of the Brothers's quarry and in the strike of its rocks lies another large quarry, Ruscher's (station 25). The same black shales, heavy sandstone banks and arenaceous limestone beds, as well as greenish shales toward the eastern part, are here exposed. Diplograptus amplexicaulis is also quite common.

Station 26. Corner of Adams and 10th streets, Troy

In the railroad cut at the corner of Adams and 10th streets in North Troy, (station 26) in a compact, black argillaceous shale Diplograptus amplexicaulis, Hall, and Corynoides curtus, Nicholson, were found. These fossils and the appearance of the rock leave no doubt of the identity of these beds with those exposed in their direct strike in the Brothers's and Ruscher's quarries in south Troy. No other exposures of these beds have been met with farther north, in the investigated area, though they undoubtedly continue in the direction indicated by the outcrops in Troy.

Extension of zone of middle Trenton beds

The five stations, 22-26, establish the presence of a zone of rocks of the general appearance of the Hudson river shales and sandstones (but containing some limestone), between Troy and Watervliet, which is about 1 mile wide and equivalent to the middle Trenton. This zone could not be traced farther south, which fact, however, finds its explanation in the topographic conditions prevailing to the south; for the strike of the middle Trenton beds brings them, as an examination of the map will show, into the alluvial plain of the Hudson river where outcrops are absent. The zone would then probably pass through the lower part of the city of Albany and could be expected along the Normans kill above Kenwood and below the Utica shale outcrops described above. But along that part of the river only one exposure is found, that at Normansville, and this, unfortunately, is not known to have ever yielded any fossils. From here to the Lorraine sandstones and shales at the base of the Helderberg escarpment no farther outcrops could be found. Both the Vlaumans and the Coeymans kills, which have been followed by the writer along their entire courses, show outcrops only near their mouths, and these belong to the next following zone. The outcrops at the upper Coeymans kill and its tributary, the Sprayt kill, have been mentioned above. On account of the general n ne-s sw strike of all the beds in this region, it can, however, be safely surmised that this zone passes under the Helderbergs.

D NORMANSKILL BEDS (LOWER DICELLOGRAPTUS ZONE)

After the presence of these zones of Lorraine, Utica and Trenton shales in the Hudson river valley had become evident to the writer, a thorough search for the graptolites of the Normans kill or lower Dicellograptus zone was instituted, this zone being, in accordance with the views of previous writers, sought for between the Lorraine and Utica, and between the Utica and Trenton zones. There has, however, no trace of these graptolites been found between or within the Utica and Lorraine zones,

while an investigation of the rocks to the east of the Trenton zone has furnished ample evidence of the presence of the Dicellograptus zone.

The following stations with these fossils were found:

Station 27. Cahill's hill, south Troy

Behind the Brothers's quarry outcrops of mostly dark shales may be followed up almost to the top of Cahill's hill, whence a small gully runs north into the Poesten kill in upper Spring avenue, south Troy (station 27). This gully furnishes a good section. In its upper part greenish gray argillaceous shales, farther down gray, somewhat sandy shales, and at the bottom softer, black argillaceous shales are exposed. The last contain graptolites in a fine state of preservation; besides Corynoides calicularis and a narrow Diplograptus which closely approaches D. amplexicaulis; well developed specimens of Diplograptus foliaceus occur in fair number. The combined presence of these indicates the transition of the middle Trenton shale of station 24 into another zone.

Station 28. Poesten kill, South Troy

The Trenton shales of the Brothers's quarry appear again across the Poesten kill in Spring avenue in a small road metal pit behind the northern row of houses. Going from here 200 yards east, along the north bank of the Poesten kill, just above Ruff's canal mills, a four foot sandstone bed is met with to the left of the road, which is overlain by black, strongly carbonaceous, argillaceous, rather thick bedded shales. These were found to contain graptolites in considerable number and in a fair state of preservation (station 19). There were observed:

Leptograptus subtenuis, *Hall* sp.
Dicellograptus intortus, *Gurley*
D. sextans, *Hall* sp.
Climacograptus bicornis, *Hall*
C. parvus, *Hall*
Diplograptus foliaceus, *Murchison* sp.

Cryptograptus tricornis, *Carruthers* sp.(=D. marcidus, *Hall*)
Corynoides calicularis, *Nicholson*
Dawsonia *sp.*
Rhombodictyon *sp.*

Of these Leptograptus subtenuis, Dicellograptus intortus, Climacograptus parvus, Dawsonia and Rhombodictyon are restricted to the Dicellograptus zones, while Cryptograptus tricornis passes from the Calciferous into the lower Dicellograptus zone, but not into the Utica or Lorraine beds. This shale is, hence, an unmistakable representative of the Normans kill or lower Dicellograptus beds, and this interesting discovery demonstrates the presence of the Normans kill fauna only a few hundred yards to the east of the middle Trenton fauna.

Following the section farther up along the Poesten kill, alternations of sandstones and black argillaceous shales are first met with, then a four foot conglomerate with black shale as matrix, at the water tower of the wire mill; above this alternations of fissile, black and greenish gray shales and finally, by gradual disappearance of the black shales, only green shales. On the other side of the Poesten kill, just below the picturesque waterfalls, specimens of Rhombodictyon were found in a black shale, intercalated in a green shale, the latter containing great quantities of fragments of algae. These shales extend eastward as far as the great fault which brought up the Cambrian beds against the "Hudson river shales".

Station 29. Mount Olympus, Troy

Another outcrop of graptolite shale was found 2 miles farther north at Mt Olympus, a landmark of North Troy, consisting of a cliff rising some 60 feet above the alluvial plain.

The deep black, fissile argillaceous shales contain:
Didymograptus tenuis, *Hall* sp. rr
Dicranograptus ramosus, *Hall.* r
Climacograptus bicornis, *Hall.* cc

C. parvus, *Hall.* cc

C. *sp. n.*[1]

Dawsoni campanulata, *Nicholson.* c

Leptobolus walcotti *sp. n.* r

Station 30. North end of Lansingburg

An exceptionally good opportunity for collecting was offered for a time by a large excavation made around the new long distance telephone power-house at the north end of Lansingburg, north of Troy. The rock consists of black, fissile argillaceous shales, black, hard, compact argillite and intercalated, green argillaceous shales. The black shale furnished:

Corynoides calicularis, *Nicholson.* In immense number

Didymograptus serratulus, *Hall.* rr

Dicranograptus ramosus, *Hall.* r

Diplograptus angustifolius, *Hall.* Completely covering some surfaces

D. *aff.* putillus, *Hall.* rr

D. foliaceus, *Murchison.* sp. c

D. whitfieldi, *Hall.* c

Climacograptus bicornis, *Hall.* c

C. scharenbergi, *Lapworth.* c

C. *sp. n.* cc

C. *sp. n.* c

The faunas of Lansingburg and Mt Olympus, which lie in the same strike and evidently belong together, differ in general aspect from that of the lower Dicellograptus fauna by the scarcity of branching forms and the strong prevalence, in species and individuals, of the biserrate graptolites, notably of the genera Diplograptus and Climacograptus. They approach in this regard the fauna of the upper Dicellograptus beds, to which they could be referred, were it not for the occurrence of a few stipes of Didymograptus tenuis,

[1]The new species of graptolites will be described in a separate, later paper.

Didymograptus serratulus and the countless numbers of Diplograptus angustifolius, these three graptolites belonging to the lower Dicellograptus zone. The general aspect of this fauna, the appearance of several new species of Climacograptus in it and the fact that the graptolite shales of Mt Olympus on one hand lie to the northwest, that is apparently above the Diplograptus amplexicaulis beds of station 27, and on the other hand closely approach the Utica beds at Lansingburg and at station 31, half a mile farther north, may be taken to suggest that we have here a separate horizon. If these beds do not represent another zone, but only a part of the upper Dicellograptus zone, the Diplograptus amplexicaulis zone would seem partly to overlie with its beds at Watervliet, and partly to be intercalated into, the lower Dicellograptus zone, at station 27, east of Mt Olympus, an irregularity which may be also caused by the complicated folding of the region, which partakes of the nature of an anticlinorium (*see* p. 557). The entire problem, however, of the relation of these beds of Lansingburg to the lower Dicellograptus and Diplograptus amplexicaulis zones awaits its solution in the tracing of the entire system farther north at some future time.

Station 31. Bluff above Lansingburg

Directly opposite Laveny's point, station 6, in a high bluff, half a mile above the Lansingburg-Waterford bridge, a fossiliferous bed was found. The soft, fissile, black shale contained:

Corynoides calicularis, *Nicholson.* r

Diplograptus *sp.* Small fragment

Climacograptus bicornis, *Hall.* c

Climacograptus *sp. n.* c

These beds probably belong to the horizon represented by the Lansingburg fauna.

Following these sandstones, black gray and greenish shales of the Poesten kill southward, a good section is met along a creek entering the river opposite Lagoon island. Here similar rocks are exposed, which, however, did not yield any fossils.

Station 32. Rensselaer

The next fossils were found in a small road metal pit at the corner of High street and Third avenue in Rensselaer (Greenbush) (station 32), where dark glazed shales and some thin gritty bands are exposed. In the shales were found some specimens of Leptograptus subtenuis and the young of a Didymograptus. The Leptograptus subtenuis is sufficient to characterize these shales as belonging to the lower Dicellograptus zone.

Station 33. Kenwood (Normans kill)

In the latitude of this station the lower Dicellograptus zone has crossed the Hudson river; for 3 miles southwest of it Hall's classical graptolite locality at the lower Normans kill (Kenwood) is situated (station 33). The rocks, exposed in a railroad cut and at the falls of the Normans kill consist of thick, partly coarse sandstone banks with intercalated, glazed, grayish argillaceous shales and some black shale from which the graptolites were obtained (described in *Pal. N. Y.*, v. 1 and 3).

Station 34. Glenmont (the Abbey)

Another locality which furnished fine material and still contains graptolites is the cut on the West Shore railroad, half a mile below the station of Glenmont (the Abbey, station 34), where similar beds with a thin black band, full of characteristic and finely preserved Normans kill graptolites, have been exposed. Southward from here, localities with this fauna have been found on both sides of the Hudson river; on the west side as far as 70 miles south of Albany (27).

Station 35. Moordener kill, Castleton

There is first the fine exposure of "Hudson river shales" and of the overthrust Cambrian beds along the Moordener kill or Murder creek extending from Castleton on the Hudson, 7 miles south of Rensselaer, to East Schodack (station 35). The section begins opposite the mill of the Fort Orange paper co. with much con-

torted black, partly glazed, argillaceous shale, which proved to be rich in specimens of Climacograptus parvus, but also furnished:

Diplograptus foliaceus, *Murchison* sp.
D. angustifolius, *Hall*
Climacograptus bicornis, *Hall*
Lasiograptus mucronatus, *Hall* sp.
Corynoides calicularis, *Nicholson*

The presence of Climacograptus parvus, Diplograptus angustifolius and Lasiograptus mucronatus places this fauna in the lower Dicellograptus zone.

CONGLOMERATE BED OF LOWER TRENTON ASPECT IN SHALE

About 150 yards farther up in the nucleus of a small anticline, a conglomerate bed with black shales above and below is exposed. The exact thickness of the latter could not, on account of the intricate contortions and the resulting swelling up and thinning out of the bed within a short space, be made out in this place, but the same conglomerate bed, or a very similar one, farther up the creek proved to be about 13 feet thick and was also inclosed on both sides by black shales. The matrix consists of a dark arenaceous limestone which weathers into a drab sandstone, while the boulders, which are all well worn, consist of small pebbles of reddish or yellowish sandstone, probably of Potsdam and Beekmantown (Calciferous) age, of large boulders (up to 1 foot in diameter) of light blue, hard Lowville (Birdseye) limestone with birdseyes and Tetradium cellulosum, Hall sp. (a typical Lowville limestone fossil), and of still larger boulders (one 2½ feet in diameter) of dark gray Trenton limestone. The latter contained:

Streptelasma corniculum, *Hall*
Callopora *cf.* ampla, *Ulrich*. c
Plectambonites sericea, *Sowerby* sp. var. aspera, *James*. cc
Strophomena incurvata, *Shepard* sp. (=Str. filitexta, *Hall*) c
Rhynchotrema increbescens, *Hall*. r

Conradella compressa, *Hall* sp. r
Pterygometopus callicephalus, *Hall.* sp. r
Isotelus *cf.* gigas, *De Kay.* c
Macronotella ulrich *sp. n.* r
Bollia *sp. n.* r

In pebbles of a very fine grained, dull black limestone were found:

Callopora ampla, *Ulrich.* c
C. multitabulata, *Ulrich.* c
Dalmanella testudinaria, *Dalman* sp. c
Platystrophia biforata, *Schlotheim* sp. c
Plectambonites *sp. n. aff.* gibbosa, *Winchell & Schuchert.* cc
Christiania trentonensis *sp. n.* r
Eccyliopterus *sp. n.* r
Pterygometopus callicephalus, *Hall* sp. c
Ceraurus pleurexanthemus, *Hall.* r
Conularia trentonensis, *Hall.* Young specimen. r

The matrix contained:

Pachydictya *sp.* c
Stromatocerium *sp.* cc
Rafinesquina alternata, *Emmons* sp. c
Plectambonites sericea, *Sowerby* sp. var. aspera, *James.* r
Strophomena incurvata, *Shepard* sp. r
Plectambonites, *sp. n. aff.* gibbosa, *Winchell & Schuchert.* r

Of these forms Streptelasma corniculum occurs, according to Hall, principally in the lower Trenton; Winchell and Schuchert report it from the lower and middle Trenton; Callopora ampla and multitabulata are both Black river and lower Trenton forms in the west; Pachydictya is principally developed in the lower and middle Trenton; Strophomena incurvata occurs according to Hall in the lower Trenton at Middleville, is reported by White from the same bed with Diplograptus amplexicaulis, and may therefore, rise into the middle Trenton; and in the west it is princi-

[1]The new fossils of this and the next station will be described in a separate paper.

pally distributed through the Stones river and Black river groups. The single species of Macronotella, made known by Ulrich (49:648), comes from the Stones river group (Lowville limestone). All the other fossils found belong either to species which lived throughout the Trenton age or to new species too different from those known to allow taxonomic conclusions.

It is obvious that the faunas of both the pebbles and of the matrix point to a low horizon in the Trenton stage which may even descend into the Black river stage. A threefold interest attaches, therefore, to this fauna, firstly that of its location in the eastern region, secondly that of the remarkable character of its components and finally, its intercalation in the Normans kill shales.

CONGLOMERATE BED ON RYSEDORPH HILL

This interest is hightened by the occurrence of another conglomerate bed on the top of Rysedorph hill or the Pinnacle, east of Rensselaer (station 36 on map), which contains the same groups of Trenton pebbles bearing the same faunas, augmented, however, by numerous other species, in part new.[1] The peculiar antique character of this Trenton fauna of Rysedorph hill finds its most pregnant expression in the numerous specimens of Ampyx hastatus sp. n. (*see* pl. 1, fig. 1) and Remopleurides linguatus sp. n. found in the same pebbles with Ceraurus and Pterygometopus. As before observed, Ami found similar antique forms in the Dicellograptus zone of the Quebec massive. The different composition of this eastern Trenton fauna when compared with the other Trenton faunas of the state, is a fitting corollary to the restriction of the Normans kill fauna, with which it is homotaxial, to the eastern margin of the state. Both faunas, together with Ami's interesting discoveries, point to conditions and connections of this eastern border sea altogether different from those of the regions to the west.

[1] This is the locality termed by Emmons (Am. geol. pt 2, p. 72) and Walcott "Cantonment hill."

One fossil of the Rysedorph hill fauna deserves special notice in this place. It is a small graptolite, several specimens of which were found in an exquisite, uncompressed state of preservation in a small, dark gray limestone pebble which within a cubic inch contained, besides the graptolites, a cranidium of Ampyx hastatus, a cephalon of Pterygometopus callicephalus, Plectambonites aff. gibbosa and a Callopora (*see* pl. 1, fig. 1). The graptolite is a Climacograptus. A careful comparison of it with all the species of Climacograptus obtained so far from the Normans kill and Utica shales of New York shows its absolute identity with a form which is quite common in the Normans kill shale of Mt Moreno near Hudson. It differs from all other species of Climacograptus by its strong sculpture and specially by the characteristic deep, strongly zigzag groove along the median line of the rhabdosome. This is a characteristic feature of Climacograptus scharenbergi Lapworth, with which it also agrees in the rectangular outline of the thecae and apparent absence of appendages. Cl. scharenbergi has been reported before by Lapworth and Gurley from the lower and upper Dicellograptus zones (the former=Normans kill zone) of Canada. It does not rise into the Utica and Lorraine beds. Its association at Rysedorph hill with a peculiar lower Trenton fauna, is, hence, a strong argument in favor of the lower Trenton age of the Normans kill shale.

In Europe this graptolite occurs at even deeper horizons; for Roemer (54:612) collected it in the Phyllograptus shales near Christiania, and Tullberg reports it from the horizons with Didymograptus geminus and Diplograptus putillus, which, in Scania, lie below the Coenograptus gracilis zone (=lower Dicellograptus zone). In Scotland it occurs in the corresponding Glenkiln shales, which also lie deeper than the zone with Coenograptus gracilis which forms the base of the Moffat beds.

The beds on Rysedorph hill which outcrop at the fault between the Normans kill shales and the Cambrian slates repre-

sent probably, as remarked by Walcott (36:319) a block caught on the line of the fault. A similar case has been made known by Vanuxem from the East Canada creek, where along a fault a Trenton limestone bed has been caught between the Utica shale and the Beekmantown (Calciferous) limestone (5:210). This would indicate that the conglomerate bed was the first resistent stratum within or below the Normans kill shales. Its similarity with the Moordener kill bed permits the conclusion that it is, like the latter, inclosed in the shales, and perhaps continuous with it. A few miles south of Castleton another brecciated limestone bed, intercalated in graptolite-bearing Normans kill shales, was discovered by Ford (*see* p. 503). This lies directly in the strike of the Moordener kill bed and is probably also continuous with it.

The conclusion to be derived from the observations on these conglomerate beds, which is of the greatest import for the present investigation, is that there is intercalated in undoubted Normans kill or lower Dicellograptus shales a conglomerate bed which, in pebbles as well as matrix, contains as its youngest fossils those of lower Trenton aspect. The occurrence of pebbles of two different kinds of limestone (even three at Rysedorph hill) means that the formation of several Trenton limestone beds must have preceded the deposition of these shales, and that an unconformity exists between the limestone and the shale. The more common fossils of the pebbles have however been found also in the matrix. This could be explained either by the assumption that some fossils became separated from the pebbles and embedded in the matrix, a view which seems to be supported by the scarcity of fossils in the matrix and opposed by the occurrence of whole specimens of such fragile shells as Strophomena incurvata and Plectambonites sericea var. aspera, James; or by the assumption that the forms entombed in the pebbles were still flourishing at the time of the formation of the conglomerate. As the conditions of living in a region where

the deposition of large boulders proceeds are evidently not favorable to a benthonic fauna, the scarcity of fossils in the matrix appears natural; and the view of the continued existence of the fauna of the pebbles, in some adjacent region, and its occasional incursion into the graptolite province seems to be the better supported. This would mean that the Normans kill graptolite fauna and the mollusk and trilobite fauna of the conglomerate with lower Trenton aspect were synchronous. The presence of Trenton fossils in so-called Hudson river shales has been proved before (*see* p. 536). So has the resting of these shales immediately on lower Trenton limestone beds in the regions to the east (33) and to the south, near Poughkeepsie (21).

Following up the Moordener kill to the base of the second falls, black shales with intercalations of hard, black chert beds and some thinner sandstone and limestone bands are passed, and at this point a conglomerate bed, 13 feet thick and flanked by thinner conglomerate beds, crosses the creek. On account of the disturbed character of the region, this bed may be identical with that first mentioned. The shales continue to the third falls, where a third conglomerate bed, 20 feet thick, is met with. Then follow coarse sandstones in layers from 2 to 4 feet thick, and sandy shales, and above them black, fissile, argillaceous shales with many thin intercalations of dark limestone and sandstone. After a break of some 300 feet, dark gray, fissile shales again appear, and these continue to the bridge over the Moordener kill on the road between Castleton and Schodack depot (Brookview). Just below this bridge, in steel gray, somewhat sandy, argillaceous shales, numerous excellently preserved specimens of Corynoides calicularis were found. This occurrence suggests that all these beds may belong to the Dicellograptus zone.

A mile and a half farther up, the creek passes again over glazed gray and black shales and bluish quartzite beds, followed, below Dickerman's mill, 2 miles below Schodack Center, by the green and purple slates and grits of the Cambric formation.

EXTENSION OF ZONE OF NORMANS KILL BEDS

(*Lower Dicellograptus beds*)

That the Dicellograptus beds extend farther south along the Hudson river is fully demonstrated by the collection made by Ford at Schodack Landing and by the rich collecting grounds of graptolites near Stockport on the Kinderhook creek and at Mt Moreno, near Hudson. An occurrence worthy of record is the alternation of indurated green slate containing fucoids, with black, graptolite-bearing shales, in a quarry at the north side of Mt Moreno where the alternating bands often do not exceed an inch in thickness.

The presence of the Normans kill fauna at the Poesten kill near Troy, at Rensselaer, the Moordener kill, Schodack Landing, the Kinderhook creek and Hudson, all east of the Hudson river, and at the Normans kill (Kenwood) and the Abbey (Glenmont), west of the river, demonstrates the presence of a zone of Normans kill or Dicellograptus beds to the east of the other zones, as a glance at the map will show. This zone may extend northward through Vermont into Canada. It has also been found in Maine (39).

TAXONOMIC POSITION OF THE NORMANS KILL GRAPTOLITE BEDS

In the region northeast, east and southeast of Albany the Normans kill zone is cut off by the overthrust fault which brought it in contact with the Cambric beds. Farther south it has been found to rest on lower Trenton limestone (33). These Trenton limestone beds, which are in the north only indicated by the conglomerate beds of Rysedorph hill, the Moordener kill and Schodack Landing, would, hence, constitute a fifth zone. Between this zone and the zone of middle Trenton shales and limestones, outcropping at Watervliet and south Troy, is now interposed the Dicellograptus zone. There can, hence, in the mass of "Hudson river shales" be discerned four zones from west to east, namely:

1 Lorraine beds
2 Utica beds
3 Upper and middle Trenton beds
4 Dicellograptus beds; these resting on
5 Lower Trenton limestone

The legitimate conclusion to be drawn from this succession of beds is that *the Dicellograptus zone is homotaxial with a part of the middle or lower Trenton limestone.* This conclusion stands in full accord with the evidence furnished by the conglomerate beds.

None of these zones, however, is entirely uniform in its fossil contents, as a comparison of the fossils from the various stations easily demonstrates. Not taking into account the difference between graptolite and mollusk beds which may be synchronous, run into each other and alternate irregularly, it is evident that the associations of fossils in some beds differ greatly from the typical faunas of their epoch.

There is first the difference between the typical lower Dicellograptus beds and the Dicellograptus beds of Mt Olympus and Lansingburg; farther the remarkable admixture of Trenton fossils and the presence of the Climacograptus caudatus, which is a typical upper Dicellograptus form, in the Utica beds of Mechanicsville, and the appearance of Cryptograptus tricornis among the Utica fossils of Van Schaick island. These latter faunas differ markedly from the typical Utica graptolite fauna of the Rural cemetery, the penitentiary and the lower Normans kill. There is finally the peculiar combination of Trenton and Lorraine forms with the Utica fauna of the old observatory and Green Island.

The full list of the various faunas observed is the following:

Lower Trenton fauna of conglomerate beds of Rysedorph hill, consisting at least of three different faunules

Trenton	Typical lower Dicellograptus fauna	
	Lower Dicell. fauna of Mt Olympus and Lansingburg	Relative position of these two faunas not yet clearly determined
	Dipl. amplexicaulis fauna	

Utica	Utica fauna of Mechanicsville with Con. trentonensis and Climacogr. caudatus Utica fauna of Van Schaick island with Cryptogr. tricornis Typical Utica graptolite fauna of Rural cemetery, etc. with Diplogr. quadrimucronatus and Diplogr. putillus Upper Utica beds of old Dudley observatory and Green Island
	Typical Lorraine beds of Waterford and Block island

Which of these minor faunas constitute constant sub-horizons of the larger divisions has not been established thus far; but it is expected that a continuation of this investigation in the areas adjoining north and south will furnish the desired information.

EXPLANATION OF THE OVERTURN OF THE STRATA

All these beds now dip east and the Lorraine beds are, hence, the lowest in the series (*see* fig. 5, p. 556). It is, therefore, necessary to assume either a series of parallel overthrusts which brought up deeper beds successively or a complete overturn of the whole series of strata. The former assumption would seem to find some support in the abundance of slickensides and small faults in some localities, as specially in the Brothers's quarry at south Troy and along Dry creek, west of Watervliet. But it could hardly be supposed that a system of larger faults could produce such a regular succession of zones following the general strike of the beds as that found in the investigated area, without repetition of zones or other irregularities. The slickensides, which are often not a foot apart, might be assumed to indicate an upward movement of the entire mass along an infinite number of small faults, such that the more easterly beds were regularly pushed a little farther up, in a manner illustrated by Van Hise (58) to show the possible great surficial elongation of the crust by small displacements along shearing joints. Under such assumption the whole orogenic movement would evidently have been uniform and would have, regularly and gradually, brought

up the deeper beds in the east, and, therefore, not interfere with our conclusion as to the stratigraphic position of the Dicellograptus zone. But slickensides and small faults abound in all folded regions, while the presence of numerous small folds as far west as the Vly and throughout the whole territory, as well as the bounding of the area by powerfully folded parts of the crust in the east (Taconic mountains), in the south by the limestone belts which traverse the shales and in the southwest by the folded parts of the Helderberg region, makes the explanation of the inversion of the beds by a system of shearing joints appear rather forced and suggests that the inversion is the result of overfolding. The writer much prefers the latter view, as it considers the inverted system of beds as a whole and as not necessarily involving a great disturbance of the original succession. It does away with those elements of uncertainty as to the unbroken succession of the four zones which would be involved in the assumption of inversion by an overthrust system. Arguments in support of this view are therefore here presented.

It is an established fact that the numerous folds of the Appalachian mountain system have their steepest slopes facing the northwest or the interior of the continent and are more or less overturned in that direction. The presence of the Appalachian system of folds in the middle Hudson valley region was first suggested by Mather (4) and asserted by Hall (15), who proved the existence in the Catskills of four lines of very low anticlinals, nearly parallel to each other and running from southwest to northeast in conformity with the ordinary trend of the Appalachian ranges; the synclinals occupying the summits, the anticlinals the bottom of the valleys. This discovery has been verified by Arnold Guyot (25).

Two years later the existence of folds of true Appalachian type in the region between the Catskill mountains and the Hudson river was reported by N. S. Shaler (18). On the other side of the river it was found by James D. Dana that the schists of Hudson river age dip under the limestone of Trenton-Calciferous age in the limestone belts of Dutchess county and western Connecticut.

I. P. Bishop (33) found the facts gathered by him in regard to the limestone belts in Columbia county "suggestive of a synclinal having the Trenton limestone outcropping on both sides, and with the edge pushed over westward." As a synclinal is only the complement of an anticlinal, these observations prove the overfolded character of the eastern Hudson valley region directly south of the investigated area. That the Taconic mountain range to the east of our territory is built after the Appalachian type has been demonstrated by I. E. Wolff (45) in an elaborate paper in which it is shown that the Hoosac mountain is an anticline. "This anticline preserves the rocks in their normal position on the east side, but on the west they are folded under in inverse position with eastern dip."[1]

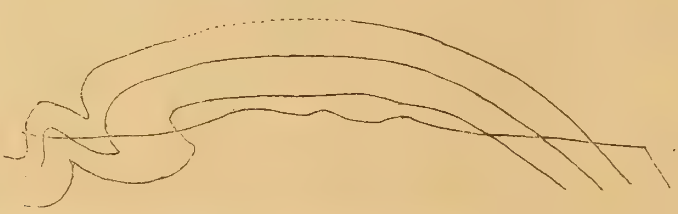

Fig. 1 Geologic profile of Hoosac mountain. After I. E Wolff. (45 pl. 6, 5a)

With the presence of folds of Appalachian type to the south and east of our region, the assumption of an anticlinal with underturned west sides to explain the inversion of the zones, does not seem to be hazardous.

It was long ago proved by the Professors Rogers (2) that the great faults in southwestern Virginia lie in the direction of axes of plications instead of in monoclinal strata and "coincide in the great majority of instances with the steep or inverted sides of the flexures." It has been farther demonstrated that overfolds often change into overthrusts, and theoretically should do so, as soon as the differential stress of the layers reaches their ultimate strength (*see* the lucid exposition of these relations by C. R. Van Hise, 52). The wonderful regularity with which these overthrust faults appear in the steep western sides of the numerous folds of the Appalachian mountain system has been fully demonstrated by Bailey Willis (43).

[1]One of the profiles has been copied to illustrate this type of mountain structure. (*See* fig. 1)

The whole system of shales from the Lorraine at Waterford through the Utica, upper (?) and middle Trenton shales and Dicellograptus shales to the Cambric slates and again to the metamorphic slates east of the Cambric zone, which have been found to be of "Hudson river age", proves by its conformability (its uniform eastern dip) that it was one in system of dislocation and one in system of mountain-making. Hence the writer feels safe in assuming that the great overthrust fault between the Dicellograptus beds and Cambric beds is a fault cutting parallel to the axial plane of an overfold, the western underturned wing of which is exposed in the four zones described in this paper.

The orogenic and physiographic stages through which this region then passed would have been:

1 A folding of Appalachian type, involving all terranes inclusive of the Lorraine beds (fig. 2).

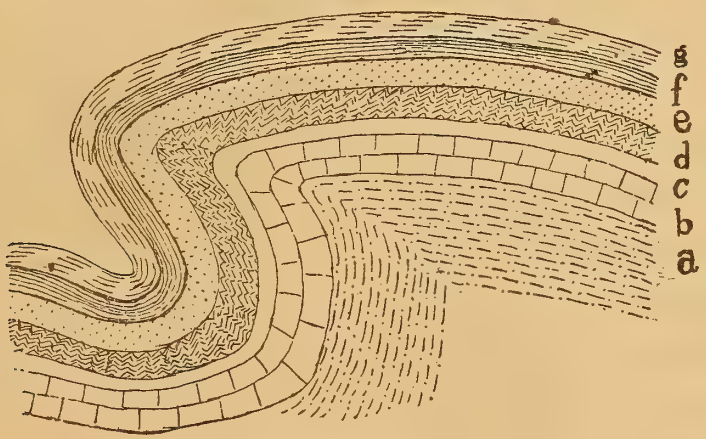

Fig. 2 Overfolding of Appalachian type (*see* fig. 1) in Hudson valley of Albany. a=Cambric; b=Beekmantown limestone (Calciferous); c=lower Trenton limestone; d=Normans kill shale; e=middle and upper Trenton shale; f=Utica shale; g=Lorraine beds.

2 The formation of a fault in the underturned wing parallel to the axial plane (fig. 3).

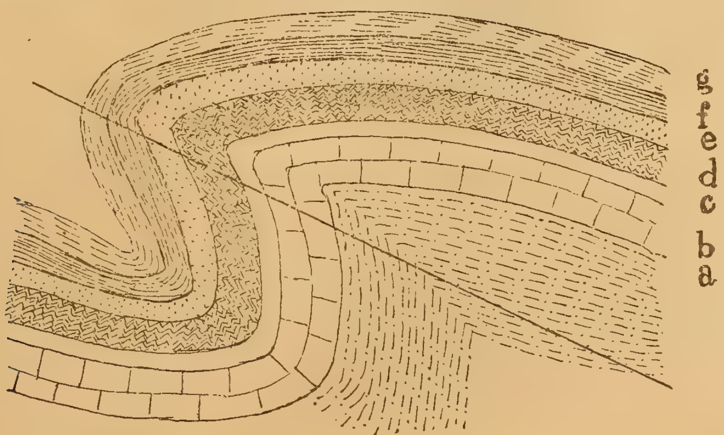

Fig 3 Fault in underturned wing of fold.

3 An overthrust of the eastern wing over the western, bringing the Cambric beds in contact with the Dicellograptus beds in the core of the fold (fig. 4).

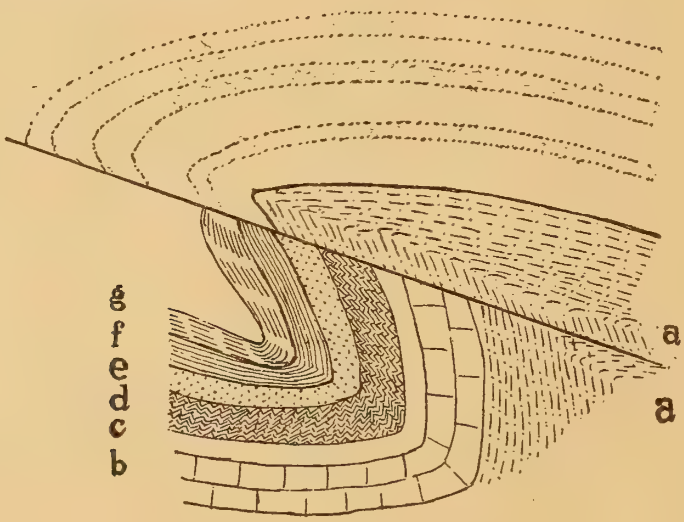

Fig. 4 Overthrust fault.

4 Reduction to a plain. The erosion, working proportionally to the elevation of the beds and, later, on the abrasion by the seas of upper Siluric and Devonic time, as evinced by the unconformable deposition of the limestones at Becraft mountain (Columbia county), on the "Hudson river" shales, reduced the surface of the disturbed area to nearly or entirely the condition of a plain, leaving the steeply dipping conformable and inverted series of beds and the overthrust fault as witnesses of the former powerful activity of orogenic forces (fig. 5).

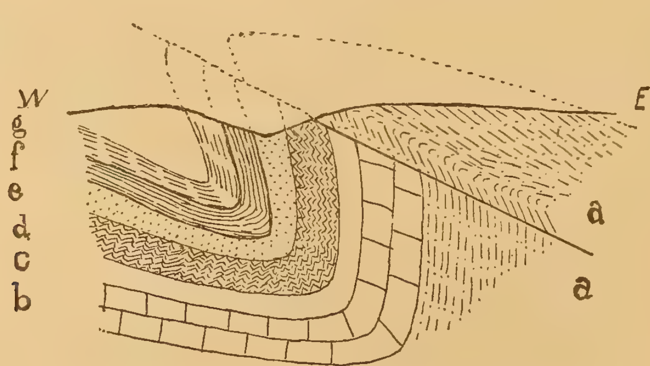

Fig. 5 Profile through Hudson valley at Watervliet.

The small anticlines crossing the Vly are the weak western manifestations of the fold-producing forces; for they run parallel to the greater deformations of the crust in the east, while the larger anticlines, pretty examples of which are visible along the

lower Vlaumans kill and in the Brothers's quarry at South Troy, probably are not merely contortions restricted to weaker strata, for the heavy sandstone banks are also involved in the folding, but, probably, partake of the nature of smaller folds riding on the larger ones, a phenomenon observable in many folded regions and which, when regularly and strongly developed, has been termed an anticlinorium by Dana. Viewed in this light these narrow, but steep folds serve as additional evidence of the presence of a larger fold of a higher order.[1] In fact it is necessary to assume the presence of such riding folds of various sizes to explain certain irregularities in the succession of the beds within the zones in this region. Thus it will be difficult to account in any other way for the presence of the upper Utica beds on northern and eastern Green Island, where we should expect the lowest Utica beds. Also the apparent intercalation of shales with Diplograptus amplexicaulis in lower Dicellograptus shales, east of Mt Olympus, may, on farther investigation, find its explanation in such minor folds.

The end which the writer has in view in discussing the tectonic relations of the investigated area is to demonstrate that the inverted position of the beds can be brought into harmony with the general structure of the whole region, and that this inversion, therefore, can not in any way be construed as weakening the conclusion drawn from the succession of the zones and the paleontologic evidence, viz that the Normans kill or Dicellograptus zone

[1]The possibility that the whole region investigated is built up of nothing but closely packed, overturned small folds, such as were found by Shaler farther south (18) and are described by Dale (63) from the slate belt, has not been discussed by the writer, though the presence of such small folds can be observed in several localities; for, on account of their small size and evident surficial character, they would not be able to produce such long and wide belts of rocks, as for instance that of the Utica shale. Dale (63:199) also reports that in his territory, the northern extension of our region, "series of such various folds form compound anticlines, and these minor Cambrian anticlinoria alternate with Ordovician synclinoria conformably overlying Cambrian ones. As the Ordovician area consists of shales, slates, grits and small quartzite beds, the beds being more heterogeneous, slaty cleavage is less prevalent, but the folds are also overturned toward the west".

is an eastern representative of part of the lower Trenton. It is hoped that this end has been attained, at least in so far that the necessity of assuming an inversion of the beds will not be considered as necessarily fatal to the above mentioned conclusion, which appears fully warranted by stratigraphic and paleontologic evidence. This evidence, which we may be allowed to sum up here to emphasize the multiformity of its character, consists in the observation of four zones, the lowest of which is the Normans kill shale; the observed intercalation of a conglomerate bed containing lower Trenton fossils; and the discovery that this shale rests on lower Trenton limestone.

CLASTIC DEVELOPMENT OF TRENTON IN HUDSON RIVER VALLEY

It seems appropriate to state here certain inferences which can be drawn from the principal conclusion of this paper, and which seem either to militate against other well known facts of the geology of New York or apparently are difficult of explanation.

There is *first* the shaly development of the mass of the Trenton in contrast to its typical calcareous character a short distance to the west; for the correlation of the Normans kill shales with part of the lower Trenton, of the Watervliet beds with the middle Trenton and the absence of limestone beds between this zone and the Utica shale zone necessitate the assumption of the replacing of the Trenton limestone principally by shales and sandstones. This view harmonizes with the well-known fact of the clastic development of the majority of the formations in the Appalachian region, to which the investigated territory, by the character of the disturbances and of those of the neighboring regions belongs. This clastic character and the great thickness of the mass of shales are both characteristic features of the Appalachian region, and of themselves constitute evidence in support of the structure indicated.

The eastward clastic development of the Trenton is farther indicated by the facts which have been gathered by others in regard to the thickness and fossil contents of this Trenton in the Hudson and Mohawk valley regions. As noted in the introduction, the fauna of the Trenton limestone has in the limestone belts to the south only a lower Trenton aspect. This limestone is directly followed by shales; hence the middle and upper Trenton beds must either be absent entirely or be represented by another facies. The possibility that the middle and upper Trenton limestone had been present and subsequently abraded (as the Trenton limestone conglomerate bed in the shales might suggest), can be disregarded on account of the presence of middle Trenton fossils in the shales. It has farther been observed by Walcott (36) that at Mt Anthony (Rensselaer county), where 400 feet of limestone occur, M a c l u r e a and M u r c h i s o n i a are found "nearly 200 feet below the shales". The Trenton limestone could, therefore, at that locality reach 200 feet at the utmost, from which figure, however, are certainly to be subtracted the measurements of the Black river, Lowville (Birdseye) and upper Chazy limestones, which reduce this figure probably by one half. In contrast to this stands the thickness of the Trenton limestone in the typical section at Trenton Falls, where though the top and bottom of the formation are covered, 270 feet were obtained by Prosser and Cumings's careful measurements (56). It is a highly interesting fact that, according to the figures obtained by the same investigators, the Trenton limestone gradually thins out in approaching the Hudson valley region. At Littlefalls only 104 feet of limestone was found between the Lowville limestone and the Utica shale; at Canajoharie and the Flat creek near Sprakers only 17 feet of Trenton limestone; at Tribeshill, 40 feet; along Morphy creek between Cranesville and Amsterdam, 37 feet; and opposite Cranesville, 21 feet; while Walcott reports only 40 feet of Trenton limestone from Saratoga, north of the region under consideration.

Hand in hand with this eastward decrease in the thickness of the limestone is a rapid increase in the thickness of the Utica and Lorraine shales. While the combined thickness of Utica and Lorraine shales in a well at Rochester, Monroe co., amounted to only 598 feet, the two formations were found to measure at Chittenango, 32 miles west of Utica, 233 and 640 feet respectively (46). Walcott reports a thickness of 710 feet for the Utica shale at Utica; and in the section along Morphy creek to the top of Adebahr hill between Cranesville and Amsterdam, Prosser (56: 649) found 1160 feet (the Trenton limestone measures there only 21 feet). In the well-boring at Altamont (37) 3475 feet of shale between the Upper Siluric and Trenton limestone was found; and in Washington county the thickness of the "Hudson river shales" has been estimated by Walcott at 5000 feet (36a).[1]

This decrease of the Trenton limestone eastward of Trenton Falls and the increase of the superjacent shales are, however, not to be understood as implying that the shaly facies of the Trenton limestone, specially the Normans kill shale, gradually replaces the calcareous facies, for the Utica shale has been found everywhere in the Mohawk valley to rest on the Trenton limestone, and the Normans kill fauna is as yet unknown west of the Hudson river valley; but it certainly shows that either the conditions for the formation of calcareous deposits throughout Trenton time became less favorable toward the east, and hence the calcareous forma-

[1]The last estimates seem not to be verified by later observers. Dale (44) observed the dwindling in the thickness of the Hudson river shales in the region east of the Hudson to "400 feet and possibly even 200 feet". This phenomenon is attributed to a replacement of the shales by grits or an erosion of the former before the deposition of the latter. The same cause is admitted as probably explaining his low estimates (1000 to 1200 feet) for the Ordovician of the slate belt in his last paper (63:179). Kimball (42) also found in Columbia county only 1285 feet of Hudson river shales, but there also the series may have been reduced by subsequent erosion.

It is to be remembered that only the Normans kill graptolites have been found thus far in the above mentioned Hudson river shales and slates; and that, if this 1200 feet represents only the thickness of the Normans kill zone, which is still to be followed by the overlying formations, middle and upper Trenton, Utica and Lorraine shales, this would bring the thickness of the entire series nearer to the figure given by Ashburner.

tion as a whole dwindled to an insignificant thickness, or that only a short span of the Trenton period is represented in the lower Mohawk valley by limestone, presumably the earliest portion, as in the Hudson valley. The facts at hand do not permit a choice between the two alternatives, but the thinning out of the limestone, together with the entire absence of the Dicellograptus fauna in the Mohawk valley, suggests the presence of a barrier, perhaps by a shallowing of the sea as indicated by the thin formation of limestone in the region of the lower Mohawk, in early Trenton time. The very peculiar Trenton fauna of the limestone conglomerate of Rysedorph hill and Moordener kill, characterized by the occurrence of Plectambonites sericea var. aspera, Plectambonites aff. gibbosa, Christiania, Eccyliopterus, Ampyx and Remopleurides, indicates a great faunistic difference between the Hudson valley and Mohawk valley regions even before the deposition of the Dicellograptus zone, and at the time of the deposition of the basal Trenton limestone beds.

DISCONTINUITY OF FAUNISTIC SUCCESSION IN TRENTON AND UTICA BEDS

A fact apparently incongruous with the separation of the Normans kill and the Utica shales by the middle and upper Trenton beds is the discontinuity of the faunistic succession in these Trenton beds; for, while the lower Dicellograptus fauna disappears in the middle Trenton shales, a small part of the graptolite fauna of the Dicellograptus zone reappears in the Utica shale. It is this observation which induced Whitfield and Walcott to connect the Normans kill with the Utica shale. On the other hand, the graptolite, Diplograptus amplexicaulis, common in the middle Trenton, disappears in the Utica shale and is said to reappear in the Lorraine beds. The latter fact is in accordance with the known return of other Trenton forms in Lorraine times. The explanation of this alternating recession and return of graptolite faunas in the Hudson valley region seems to lie in the distribution of the faunas and the character of the associate forms.

While the Dicellograptus fauna occurs only in the Appalachian region, Canadian basin and the far west and Pacific region, but not east of the Mississippi, Diplograptus amplexicaulis is also found in the Trenton of central New York (Middleville, Trenton Falls) and in the Lorraine beds of northwestern New York (Turin), and in Iowa (J. F. James, *loc. cit.*). The fauna found by Ami associated with the Dicellograptus fauna in the Quebec region and the fauna of the conglomerate beds of Moordener kill and Rysedorph hill, are different in strong features from the Trenton of the rest of New York and the states directly southwest of it. Here is the genus Christiania, which has not been found in the Lower Siluric of North America, but lived at that era in European waters, the Bohemians genus Paterula, which is well represented in the Normans kill shales and which besides has been found only in Canada and is therefore restricted to the continental margin; the trilobite genera Agnostus, Aeglina (rediviva Barr. ?), Ampyx, Dionide (?), observed by Ami with the Normans kill graptolites, and the genera Ampyx and Remopleurides in the conglomerate bed of Rysedorph hill, all forms which had apparently become extinct in the typical Trenton of New York, but continued to live in Europe. Furthermore, as the Normans kill graptolite fauna has been found by Lapworth to be an exact correlate of a European graptolite zone, the conclusion seems to be unavoidable that the Normans kill or Dicellograptus fauna was foreign to the American continental platform east of the Mississippi but was at home in the oceanic basins of lower Trenton time and entered North America along the eastern continental shelf.

The middle Trenton shales of south Troy and Watervliet are, by the occurrence of Diplograptus amplexicaulis, and Proëtus parviusculus, connected with the Trenton of Trenton Falls and the eastern Mississippi basin.

The Utica graptolite fauna is again fully represented in Europe, and quite certainly entered the North American continent from the northeast, as asserted by Matthew (47) and the writer (55). Perhaps, as suggested by Frech (54. 2:100) the highroad

to Europe was already opened in the younger Trenton period; for Isotelus gigas and Trinucleus concentricus (=ornatus Stbg.) appear already in the Caradoc and its equivalents. Triarthrus becki, the most characteristic form of the Utica shale, seems to occur already in the Chasmops limestone of Sweden. In the later Utica age the Lorraine fauna from the western part of the state seemed to gain the ascendancy, as indicated by the fauna discovered by Beecher near the old Dudley observatory at Albany and by the writer on Green Island.

The Lorraine fauna, with its close relationship to the Trenton fauna in identical or vicarious forms (a relationship which becomes still more emphasized toward the interior of the continent in the overlying Richmond beds) is again evidently an epicontinental fauna derived from the Trenton fauna.

To state it more concisely, the writer believes that the Trenton fauna and its derivative, the Lorraine fauna, are of epicontinental origin, and entered the Hudson valley region from the west, while the Dicellograptus fauna and its derivative, the Utica fauna, are foreign to the continent, and entered it from the Atlantic ocean by way of the Canadian basin. This follows from the necessary assumption of the presence of a Paleo-Appalachian continent (*see* Frech, 54) to the east of North America. The former assumption seems to be supported by the indications of the presence of a ne—sw current in the Mohawk region during the Utica epoch, found by the writer in the prevailing arrangement of the graptolites, cephalopod shells, sponge spicules, etc. in the shales (55). Lapworth, followed by Walther, maintains (53) that the graptolites were planktonic or rather pseudo-planktonic animals which, drifting along the coasts, left their remains in the quieter waters at a certain distance from the coast. This view would also suggest that the Trenton and Utica shales were formed along the continental shelf under the influence of currents entering from northeast. The alternations of coarse, mostly barren sandstones with fine grained, muddy graptolite-bearing deposits indicate the changing conditions along this coast shelf, which, on the whole,

were very unfavorable to the Trenton fauna, then flourishing in the clear waters on the continental platform. During the Utica epoch the mud-bearing currents encroached on the eastern part of the continent and drove out a part of the Trenton fauna.[1]

DISCUSSION OF THE VALIDITY OF THE TERM, "HUDSON RIVER GROUP"

The demonstration of the presence of Trenton, Utica and Lorraine faunas in the shales of the Hudson river valley, necessitates a renewed investigation of the validity of the old term, "Hudson river group", or its modification, "Hudson group", as proposed by Walcott for all the beds between the Trenton limestone and the Upper Siluric. As the term has been so ably and forcibly defended by such authorities as Hall (17) and Walcott (36a), its validity can be questioned only after obtaining new facts. These,

[1]A parallel case to the continued appearance of genera in the Quebec Dicellograptus shales and the conglomerate of Rysedorph hill, which have disappeared in homotaxial beds of other regions of eastern North America, is the continuation of Trenton forms which nowhere else have been observed to go above the Trenton, as Parastrophia, hemiplicata, Cyclospira bisulcata, Clionychia undata Spyroceras bilineatum, Cyrtoceras annulatum, Cryptograptus tricornis, and Climacograptus caudatus, into beds which by the general character of their fossil contents are characterized as being of Utica age. This phenomenon has been observed in several localities, at the Dudley observatory by Dr Beecher, in two outcrops on Green Island, one on Van Schaick island, and one south of Mechanicsville by the writer. The beds near Mechanicsville may be here excluded as being evidently transitional between the Trenton and Utica epochs, or of oldest Utica age, but the other beds lie at or near the top of the Utica terrane and yet contain Trenton forms still. This peculiarity in the composition of the Utica faunas is, to the writer's knowledge, restricted to the Hudson valley region, and therefore, marks a regional difference in the character of the Utica faunas. This conclusion is supported by the distribution of Corynoides curtus mentioned before. This graptolite disappears in the Utica beds of the middle Mohawk valley, while it fills the beds of the lower Mohawk and the Hudson valley, and is also common in the Utica shale just above the Trenton at the Panton shore of Lake Champlain. Also the variety of Plectambonites sericea with wrinkled cardinal margin, mentioned before, is a fossil which extends in this region from the lowest Trenton into the upper Utica beds, and is rarely observed outside of it.

the writer trusts, have been secured in sufficient quantity to justify a reopening of the discussion.

Both investigators based their defense of the term on the supposition that the entire series of the Hudson river shales, though in diminished thickness, continued into the Mohawk valley, and that these, like the Mohawk valley shales, represented only the lapse of time between the Trenton and Medina formations. This supposition, though at that time warranted by the facts at hand, has now proved to be only partly correct; for only the Utica and Lorraine shales of the Hudson valley continue westward, while the apparently enormous mass of Trenton shales does not leave its confines. The term could then be applied only to the shales in the Hudson valley north of Cohoes and in the hills on the west side of the valley as far south as Albany, while the shales all

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These two differential features of the Utica faunas of the Hudson valley, viz, the ascension of the Trenton forms and the restriction of the different faunal composition to the marginal region, are evidently to be traced to the same cause. The assumption that these Trenton forms continued to live in Utica time in the adjoining Atlantic basin, while they had become extinct on the American continental platform, and thus were enabled to leave their shells in the deposits of the eastern continental shelf, seems to offer a reasonable explanation.

At the same time it is evident that in this region the change in physical conditions from the Trenton to the Utica epoch was by no means so profound as in the Mohawk valley and west of it; for there Utica mud shales follow more or less pure Trenton limestones, and here the deposition of clastic sediments was uninterrupted from the lower Trenton to the top of the Lorraine. Such forms as in Trenton time were accustomed to live under conditions that led to the deposition of mud and sand had of course a much greater chance to continue living when the Utica time was ushered in, in such easy stages as are apparent at Mechanicsville and on Green Island, than the faunas farther west. But it is, then, pertinent to ask why these forms did not wander with their new Utican companions, which came across these marginal areas on the continental platform, into the interior. This latter fact and the restriction of the graptolite, Corynoides curtus, to the east suggest again that this regional difference is of a character similar to that between the Hudson river Trenton and the continental Trenton, viz, a difference between the oceanic fauna, encroaching on the continental margin, and the fauna of a shallow continental and partially inclosed sea.

along the river from Watervliet and Troy southward would have to be excluded as being of Trenton age. The term would, hence, become misleading. But, even if it should be desired to retain it for the Lorraine and Utica zones, the objection would have to be raised that these are nowhere exposed in typical sections with their upper and lower boundaries and with their typical faunas in the Hudson valley, while these conditions which would appear absolutely necessary for the proper definition of a stratigraphic term are satisfactorily fulfilled in the neighborhoods of Utica and Lorraine, as shown by Walcott and Emmons. The writer holds, therefore, that the term "Hudson river group" for the terranes between the Trenton and Medina (Oneida) formations should be dropped. Clarke and Schuchert (62) have proposed the term, "Cincinnatian", for this interval in the geologic time scale of North America. This term has the advantage of derivation from a region where not only the Utica and Lorraine beds are fully developed, but where also a stage which intervenes between the Lorraine and Upper Siluric age, and which is missing in New York, viz the Richmond stage, is present.

It would hardly be appropriate or practical to transfer the term, "Hudson river shales", to the shales of the Normans kill or Dicellograptus zone, which indeed is fully developed in the Hudson river valley and is seen there to rest on lower Trenton limestone and to be overlaid by middle Trenton shales. As a facies which faunistically and lithologically differs strongly from the synchronous lower Trenton limestone, it certainly deserves to be designated by a separate name. Ami used the term, "Quebec or upper division of the Quebec group", for the same facies, while Walcott, in the discussion following the reading of Ami's paper, suggested that the term, "Quebec", be restricted to this upper division alone in distinction from "Lévis" etc. In the Quebec massive the beds are cut off from the neighboring terranes by faults, and their taxonomic position can not be fixed conclusively by the stratigraphy of the region, but the equivalent shales of the Hudson river valley are well defined in their stratigraphic position.

Lapworth, in correlating the Canadian with the British graptolite shales, transferred his term, Coenograptus gracilis zone, to the corresponding Canadian and Normans kill beds. He discerned a closely related zone directly above this, which, in his opinion, differed by the absence of Coenograptus gracilis. Ami, however, subsequently also found that graptolite in this second zone. The two zones were then termed lower and upper Dicellograptus zones (50). But these terms are not fully appropriate, because there have been already distinguished two Dicellograptus zones in England (those of D. complanatus and D. anceps), which lie above the zone with Coenograptus gracilis, and one in Sweden by Tullberg, which lies above the beds with Diplograptus pristis and D. quadrimucronatus. It would seem more correct to designate these American graptolite shales also by their most characteristic species, a task which must be postponed till after a closer investigation of the vertical distribution of the graptolites and the possible more detailed division into graptolite zones of the graptolite beds of the entire middle and upper Lower Siluric. Meanwhile, and perhaps even then, the term, *Normans kill shales,* may be of good service in designating this graptolite bearing, clastic facies of the middle Lower Siluric.

SUMMARY

This paper purports to demonstrate the presence of four zones of shales in the "Hudson river shales" of the Hudson valley region about Albany. These zones, which extend from n ne to s sw consist, going from west to east, of shales containing the Lorraine, Utica, middle Trenton and Normans kill graptolite faunas. The shales last named include lower Trenton conglomerate and rest on lower Trenton limestone. This succession of zones places the Normans kill graptolite beds, which form the mass of the "Hudson river shales" in the Hudson river valley, between the middle and lower Trenton and determines, together with other facts, the lower Trenton age of these shales.

The beds lie conformably inverted, on account of their being the remnant of the underturned wing of an overturned fold of Appalachian type. This fold has turned into an overthrust fault, which brought the Cambric beds as the next succeeding terrane above the Normans kill shales.

On account of the fact that the mass of beds hitherto called Hudson river shales and correlated with the Lorraine beds of central New York, is composed of terranes ranging from the Lorraine to the lower Trenton, and on account of the lack of a fully representative fauna and of a complete section of the Lorraine portion of these terranes, it is proposed to drop the term, "Hudson river shales", for the uppermost part of the Lower Siluric, and the term, "Hudson river group", for the Utica and Lorraine beds, and to employ the term Normans kill shales for the clastic facies of a part of the lower Trenton which is characterized by the graptolite fauna at the Normans kill.

DESCRIPTIONS OF NEW FOSSILS FOUND IN THE DESCRIBED SHALES

§ 1 BRACHIOPODA

With the exception of a few brachiopods no fossils which could assist in establishing the age of the Normans kill shales have been found associated with the graptolites. These are small chitinous shells which, being invariably strongly exfoliated and macerated, have so far not admitted of identification, and are, in the literature, usually mentioned as "oboloid shells". Bishop (33) speaks of several species of Lingulops.

The shales of Mt Moreno near Hudson have furnished small accumulations of such shells, which, similar to the accumulations of specimens of Leptobolus insignis in the Utica shale, appear to have been caused by drifting. Some of these valves have proved to be so well preserved that they deserve notice. Three different forms have been made out.

1 Paterula amii, *Schuchert.* Synopsis Amer. foss. Brach., bul. U. S. geol. sur. 87: 301

Paterula (?) sp., *Hall* and *Clarke.* Pal. N. Y. 1892. v. 8, pt 1, pl. 4, fig. 1 (*see* pl. 1, fig. 2)

This is one of the more common forms in the shale. It is characterized by its oval outline, broad marginal border, narrow, marginal pedicle fissure, radiating muscular impressions, and its rather strong, lustrous and well preserved shells.

The dimensions of the figured specimen were 3 mm (length) and 2.5 mm (width).

As the specimens which were sent to Professors Hall and Clarke by Mr Ami came from the beds of the city of Quebec, which contain the same graptolite fauna as the shales of Mt Moreno, it is very probable that the forms from the two localities are identical.

2 Leptobolus walcotti sp. n. (*see* pl. 1, fig. 6-12)

The most common brachiopod is a larger shell of subcircular outline, as usually preserved, very slightly convex and provided

with strong concentric and apparently regular, radiating corrugations. The latter become obsolete toward the lateral margins. The extreme thinness of these corrugated shells suggests that they are much macerated, and only one shell layer preserved. As similar corrugations occur in exfoliated and compressed specimens of Leptobolus insignis, where the characteristic, fine radiating striae of the inner layer develop under like conditions into a system of wrinkles, the supposition seems legitimate that these corrugations are only the result of maceration and compression of an originally more convex shell. This supposition is strengthened by the occurrence of less corrugated shells, furnishing various transitions to thicker, smooth, unexfoliated valves. The latter, instead of becoming corrugated, yielded to the pressure by breaking radially in two or more segments (*see* fig. 12).

The presence of a strong median septum, a pedicle-groove, traces of curving laterals and a posteriorly situated median muscular scar in the brachial valve, as well as of a narrow pedicle-groove below the beak of the pedicle-valve, indicate its position in the genus Leptobolus.

It differs from all other species of Leptobolus by its larger size. Young valves closely resemble specimens of Leptobolus insignis, but differ in being less convex, having a less prominent beak, a thinner shell and specially a more regular and finer concentric striation.

Dimensions. The largest specimen observed attains a width of 10.2 mm and a length (not fully preserved) of 8 mm.

Lower Trenton. Normans kill shales. Kenwood and Glenmont, near Albany, Mt Moreno, near Hudson.

3 Schizotreta papilliformis sp. n. (*see* pl. 1, fig. 3–5)

A third very rare form among the brachiopods of the Normans kill shales has been recognized as a new species of Schizotreta.

Diagnosis. Pedicle-valve subcircular, depressed conical, sloping equally in all directions, beak abruptly projecting just behind

the center, not procumbent in any direction; pedicle-groove begins on top of beak, is deepest directly behind the beak and becomes shallower toward the margin, to which it extends. Surface covered by very fine, regular, concentric growth lines which are not interrupted by the pedicle-groove. Shell apparently quite thick; not so much flattened as those of other forms.

A low convex shell with two posteriorly diverging oval muscular scars may represent the corresponding brachial valve.

Dimensions. Length of type specimen, 3 mm, width 3.2 mm.

This form differs from Sch. ovalis, Hall and Clarke, of the Trenton, by its subcircular outline and more central position of the beak; from Sch. conica, Dwight, also from the Trenton, by its smaller convexity and equal slope. It has the circular outline and regular concentric striation in common with Sch. pelopea, Billings sp., from the Canadian Trenton and Galena shales and Salmon river (Hudson river) formation of Minnesota (49: 365), and with the interesting Sch. minutula, Schuchert and Winchell (p. 366). The latter occurs in abundance associated with stems of Diplograptus in the "lower portion of the Hudson river group near Granger Minnesota" (=Utica shale). Sch. papilliformis differs from both these species in size, the more central position and more abrupt elevation of the beak or apex, and in the presence of a distinct pedicle-groove instead of the apical circular pedicle opening of the others.

It will be seen that these minute brachiopods do not directly determine the position of the Normans kill graptolite shales, as all three species are peculiar to this horizon, but their relationship to Trenton and Utica forms of the genera Leptobolus and Schizotreta, would certainly suggest the Trenton-Utica age of the shales in question.

It is certainly peculiar that only these minute, thin-shelled, non-calcareous brachiopod valves and no other fossils occur associated with the graptolites. Their size, thinness and the composition of their shells indicate strongly that they led a pseudoplanktonic life. Winchell and Schuchert suggest that Sch.

minutula was attached to stems of Diplograptus; the writer has noticed several cases of apparent attachment of valves of Paterula to rhabdosomes of graptolites in the shales of Mt Moreno. Farther, the accumulation of these shells in small heaps must be considered as indicative of a preceding drifting of this slowly settling organic detritus.

§ 2 PELECYPODA

Technophorus cancellatus sp. n. (*see* pl. 1, fig. 19-25)

Shell small, moderately convex, elongate, length twice the hight, greatest length in about the middle, subalate posteriorly; cardinal margin short and straight, anteriorly longer, slightly concave posteriorly; anterior end rounded, ventral margin first convex, then gently concave, the postero-basal part produced, the posterior margin slightly concave, vertical; postero-cardinal angle slightly truncate; beak sub-anterior, of moderate size and convexity, little elevated above the hinge line.

Surface uniformly convex in the middle and anterior parts, with a broad, shallow depression extending from the beak to the postero-ventral margin; post-cardinal slope with two straight, diverging, strongly projecting angular ridges or folds, which extend to the postero-ventral angle, and are separated by a rounded, ventrally deepening sulcus; posterior wing traversed by another oblique and shallower depression and posterior extremity slightly raised. Surface marked by equal filiform, concentric lines, which on the anterior and middle parts pass parallel to the ventral margin, between the post-cardinal ridges turn upward, and on the posterior wing swing obliquely forward; these are crossed on the anterior and middle parts by another system of vertical, more closely arranged thread-like lines, which in smaller specimens appear only between the concentric lines, in larger specimens become continuous and more prominent than the latter.

Casts with a deep, backward curving impression in front of the beak and a corresponding shallower, forward curving impression

behind the beak; both connected ventrally from the beak by a slight impression, causing the beak to project more strongly in casts.

Muscle impressions and the character of the hinge have not been observed.

Dimensions. Largest specimen: length 12.3 mm, hight 6.6 mm, thickness 1.8 mm; another specimen measured respectively 8x5x1.5 m; another 9x5.3x1 mm; a fourth 8.6x5.5x2 mm.

This form, which belongs to the peculiar and not yet fully understood Siluric group of lamellibranchs, for which S. A. Miller (*North American geology and paleontology*, 1889. p. 514) introduced the generic name Technophorus, and of which E. O. Ulrich described several species, has its nearest relative in Technophorus subacutus, Ulrich from the upper part of the Trenton limestone of Minnesota, which, however, is known only in casts; the casts of the two species differ materially in the charater of the beaks, in the cardinal and general outline. Our species differs from all other congeneric forms whose surface sculpture is known, by its cancellate surface.

Upper Utica shales of northern Green Island, Albany co. N. Y.

§ 3 ANNELIDA

Certain layers of the Utica graptolite shales of the Rural cemetery near Albany are profusely covered with worm-shaped carbonaceous films. The actual presence of organic matter, the uniform dimensions of certain types and the distinct terminations of the fossils leave no doubt that they represent not mere tracks but actual bodies of animals. Two types could be made out of sufficient perfection to warrant their being named and described.

Eopolychaetus albaniensis gen. nov. et spec. nov. (*see* pl. 1, fig. 13)

Head distinctly separate from the body, semicircular, with a median oval depression which extends a little on the first body segment.

Body long, slender, of approximately equal width, distinctly segmented, segments about half as long as wide, apparently convex, each provided with five to eight annulations and long setae on one side (dorsal side?) which apparently were not tufted.

Posterior end not well observed, apparently rounded.

Dimensions. Type specimen: length 13 mm, or more, (specimens of much greater length observed), width 1.2 mm; length of segment .7 mm, length of setae 1.4 mm.

While, with the material at hand, the exact systematic position of this worm could not be established with certainty, it seems clear that this type belongs to the class Polychaeti. To express this taxonomic date the generic term, Eopolychaetus, is proposed for worms with similar, slender, cylindric, regularly annulated bodies and long non-tufted setae on one side. The presence of another worm with setae was made known by E. O. Ulrich, who found tufts of long setae in the Cincinnati group (*Jour. Cin. soc. nat. hist.* 1878. 1:91).

Pontobdellopsis cometa, gen. et spec. nov. (*see* pl. 1, fig. 14-18)

Body cylindric or rather long conical, regularly tapering and abruptly terminating (with ring-like section) at wider end. Other (anterior?) end provided with chitinous disk, the latter sometimes with central depression.

Segmentation coarse; 6 segments in 2.9 mm; segments smooth, apparently not annulated; no appendages observed; test thick (strong carbonaceous film).

Dimensions. Length of largest specimen observed, 11.7 mm and width at broadest end, 1 mm.

This small but common and characteristic form has been termed Pontobdellopsis in allusion to its similarity to the recent genus Pontobdella, from which, however, no close systematic relationship of the fossil with that highly specialized genus of recent worms is claimed.

The form is most common in the Utica shale of the Rural cemetery near Albany, but it has also been observed in the lower Utica shale of Mechanicsville.

§ 3 CRUSTACEA

Ctenobolbina.

Several different forms belonging to this genus, which has, hitherto, not been reported from this state, were found at various horizons. They are:

1 Ctenobolbina cilata, Emmons sp. var. cornuta, var. nov. (*see* pl. 2, fig. 5-7)

This form differs from the typical Ctenobolbina ciliata in having the posterior lobe not so round and bulbous, and the middle lobe produced into a long, stout, blunt spine. The latter it has in common with a variety described by Ulrich (*Jour. Cin. soc. nat. hist.* 1890-91. 13:109) as Ctenobolbina ciliata var. curta, from the lower (Utica) shales of the Cincinnati group. It differs from this western relative in being relatively longer, having the principal and posterior furrow fully as wide as the type of the species and possessing a well developed frill. Both forms, which occur in homotaxial beds, represent an early divergence from the typical direction of development of the genus by the production of an elevated process, thus forming a separate section of the species; in a very similar manner as the species of Ceratopsis, Ulrich (as Beyrichia oculifera, Hall) differ from those of Tetradella by possessing an elevated process. The remark of Mr Ulrich that these processes in Ceratopsis (*loc. cit.* p. 113) are not a "mere ornament" but of a certain classificatory value, would be also pertinent in regard to the two horned varieties of Ctenobolbina ciliata; and it may at some time become necessary to unite them under another generic name.

Dimensions. Length 1.45 mm, hight .80 mm.

Lower Utica shale of Mechanicsville, Saratoga co. N. Y. Upper Utica shale of Green Island, Albany co. N. Y.

2 Ctenobolbina ciliata, Emmons sp. (*see* pl. 2, fig. 8, 9).

Typical specimens of Ctenobolbina ciliata have been collected at Green Island and at Menands (stations 10 and 11);

at the latter place with a remarkably strong development of the sulci, which extend nearly to the ventral margin, leaving the middle lobe projecting as a prominent sharp ridge.

Upper Utica shale of Green Island and Menands, Albany co. N. Y.

3 Ctenobolbina subrotunda sp. n. (*see* pl. 2, fig. 1, 2, 3, 4).

E. O. Ulrich, who made an exhaustive study of these forms and described the species of Ctenobolbina occurring in the Cincinnati beds, reports also two new species from the Trenton beds of Minnesota (49:674, 675). To these can be added a new species found in the middle Trenton shales of Port Schuyler (station 23).

Valves shortly subovate, strongly convex, dorsal margin nearly straight; ventral part approaching a semicircle in outline; sulcus wide and deep, beginning near the middle of the dorsal margin, oblique, curving backward below, dividing the carapace into two subequal lobes, which are broadly connected in the ventral region, the posterior lobe distinctly rounded and inclined to be a little larger than the anterior; both lobes equally convex, with a thick (?) edge anteriorly and posteriorly; surface minutely granulose.

Dimensions. Length .56 mm, hight .37 mm, thickness .17 mm; length of a smaller carapace, .48 mm, hight .34 mm, thickness .20 mm.

These minute valves are undoubtedly closely related to the two Trenton species of Ctenobolbina described by Ulrich. They fully agree with them in the presence of only one sulcus which is strongly curved and of two bordered lobes; but they differ from the one (Ct. fulcrata) in having the posterior bulb already farther advanced, and from the other (Ct. crassa) by the lesser development of the border and the shorter, more rotund outline. Ctenobolbina subrotunda differs from Ct. duryi, S. A. Miller sp. (*Cin. quart. jour. sci.* 1874. 1:232), a similar form from the "Hudson river group" of Cincinnati in being relatively much higher and having the sulcus more medially located.

Turrilepas(?) filosus, sp. n. (*see* pl. 2, fig. 13, 14, 15).
In the lower Utica shale of Mechanicsville, two plates were found, which in size, outline and surface ornamentation greatly differ from the minute plates of Lepidocoleus jamesi, associated with them in great number. Both plates, though of different size, are so clearly alike in outline and sculpture that they undoubtedly belong to the same species.

Plates obliquely subtriangular, comparable in outline to an isosceles triangle with the apex pushed to one side; the nucleus falling into the apex, and the two legs standing nearly vertical on the slightly convex base; the lengthened side strongly convex, the shortened nearly straight; surface marked by strongly elevated, very regular concentric lines, which have multiplied more rapidly on the posterior side.

Dimensions. The smaller specimen measures 4 mm along the base, and 4.5 mm along the vertical side; the larger 7 mm and 9 mm in the same directions.

Both valves figured differ markedly from the typical plates of Turrilepas by their outline, the absence of the sigmoidal curvature in the base, their relatively larger size, and the character of the concentric striae, which appear not as the edges of imbricating layers, but as strongly elevated lines with deep, even interspaces and by the conical shape which they probably possessed originally; for they present the appearance of convex bodies which became flattened in fossilization. This is specially distinct in the smaller specimen (pl. 2, fig. 13), where a median furrow or break separates two differently convex halves. In all these features they agree with another group of valves which have been doubtfully referred to Turrilepas by Whitfield (*Annals New York acad. sci.* 1882. v. 2. no. 8. p. 217) and by Hall and Clarke (*Pal. N. Y.* 1888. 7:219). The latter authors remark "that it is difficult to see how the combination of these subconical bodies in vertical ranges could produce such a scaly peduncle or capitulum as existed in Turrilepas" and point out their resemblance with Spathiocaris. This form (Turrilepas (?) newberryi), from which ours dif-

fers only by the stronger elevation of the concentric lines, is restricted to the upper Devonic (Cleveland shales), while Turrilepas (?) filosus occurs in the middle Lower Siluric. The occurrence of these valves of equal structure at such widely separate epochs can serve only to strengthen the belief in their representing a different and persistent type of crustacean structure.

Pollicipes siluricus sp. n. (pl. 2, fig. 16-24).

In the Utica shales of Green Island and Mechanicsville occur variously shaped valves in considerable number, which by their peculiar shapes, the arrangement of their growth lines and their shell structure, differ from the valves of all mollusks associated with them in the same rock. A suggestion of Dr Clarke as to their possible crustacean nature led to the astonishing discovery that they all find their homologues in parts of the capitula of the pedunculate cirriped genera Scalpellum and Pollicipes, notably of the latter. On this account the various valves have been united under the caption, Pollicipes siluricus, in full consciousness of the enormous gap existing between the appearance of this Lower Siluric type and the next Upper Triassic (Rhaetic) representatives of these genera. But the analogous case of the related Balanidae might be cited in support. Charles Darwin, in his classic memoir on the fossil Cirripedia,[1] stated that in the sessile Cirripedia, or Balanidae, the negative evidence of their not being found in primary or secondary formations is of considerable value, considering their great number where they appear, their strong shells, etc.; and yet, meanwhile, undoubted Paleozoic genera of Balanidae (Protobalanus, Palaeocreusia) have been found, leaving the long interval from the Devonic to the Cretaceous without any representatives of this family. It is an interesting query, what were the conditions of marine life that suppressed the Lepadidae and Balanidae, which today fill the oceans with such vast

[1] A monograph of the fossil Lepadidae, or pedunculated cirripedes of Great Britain. Palaeont. soc. 1851.

numbers of individuals that, Darwin writes, one could call the present age that of the cirripeds, in all the time from the Devonic to the Upper Jurassic. The long suppression of the mammals in Mesozoic time and their sudden rise at the beginning of the Cenozoic time seems to be an analogous case from the terrestrial fauna.

The valves have been tentatively described by terms of such valves of Pollicipes and Scalpellum as they most resemble, with which it is not so much intended to assert their actual homology as to designate them by names, and to emphasize their great similarity to the parts of the capitula referred to.

1 Tergum. Convex, elongate subrhomboidal to subtriangular, as the upper and lower carinal margins blend into each other. Carinal margin the longest, rounded; scutal margin gently rounded, about twice as long as the occludent margin. Occludent margin and upper part of carinal margin meet at an angle of over 45°, occludent and scutal margins at about 135°. From the apex to the sharp basal angle, a strongly projecting, angular, strongly curved conspicuous ridge runs at about one fourth of the entire width of the valve from the carinal margin; the surface slopes,apparently on account of lateral compression, much steeper away on the carinal side. A wide depression with a central, broad but low, slightly curved ridge extends from the apex to the middle of the scutal margin.

The surface is covered with unequal, somewhat lamellose growth lines, running parallel to the base of the valve. Where the shell has become exfoliated, regular rows of pustules running parallel to the keel become visible. These probably represent a system of pores within the corium.

It is specially this valve that, in its outline, diagonal keel, direction of growth lines and curved fold on the larger face, fully agrees with the terga of some species of Pollicipes.

2 Carina. Lanceolate fragments are thought to have been part of the carina. The fragment figured apparently had two equal wings and a median, highly prominent, angular keel (an-

gulation probably exaggerated by lateral compression). Growth lines obliquely pennately arranged, turning subparallel to the margin in the flat marginal border. A faint depression and ridge running parallel to the keel are observable on either wing. The longitudinal rows of pustules are very prominent, wherever the shell is exfoliated.

While this valve, in its long, lanceolate form and long, oblique basal margins, reminds one of the carina of Scalpellum, it lacks the angles, separating the tectum from the parietes and intra-parietes, which are characteristic features of that genus. The possibility that this valve could be a laterally compressed and extenuated tergum is excluded by its symmetric form.

3 Rostrum. Small, thick-shelled, symmetric, forming two sides of a tetrahedron; apex incurved (flattened in the figured specimen by compression, as indicated by a break); keel strongly elevated, angular, broad; surface with strong unequal growth lines running parallel to the basal margin.

This valve bears a strong resemblance to the rostrum of Pollicipes carinatus, which, however, has a flat-topped keel.

4 Upper latus. Small, little convex, six-faced, eight-sided, thick-shelled; two middle faces forming a high, basally widening keel; other faces nearly flat; surface with fine, concentric growth lines; broad, concentric undulations, crossed by fine radial striae, on the two extreme faces and along the basal margin.

This valve has been termed an upper latus on account of its similarity to the upper latera of Scalpellum quadratum and Sc. fossula. The general form of this valve is very much like that of some of the problematic Pterothecas described by Hall from the Trenton, and by Barrande from the Bohemian Siluric. As our specimen however, agrees in the nature of its shell with the valves of Pollicipes with which it is associated and can be referred to a part of the capitulum of this crustacean, it seems at present more profitable to unite it with the latter than to compare it with the still entirely problematic Pterotheca.

Dimensions: Tergum: length along keel, 9.5 mm, width 6.7 mm; length of another specimen (not complete) 13 mm, width 7 mm. Scutum: length along keel, 12.5 mm, width 7.5 mm. Carina: length of specimen (upper third missing) 12.3 mm, width 10.2 mm; length of other large fragment, 16 mm, width 10 mm; width of another fragment, 7 mm. Rostrum: length along keel, 8.3 mm, width 4.7 mm. Upper latus: length 6.7 mm, width 8 mm.

Lower Utica shale of Mechanicsville, Saratoga co. N. Y. Upper Utica shale of Green Island, Albany co. N. Y.

DESCRIPTION OF MAP

The roman figures indicate the localities which furnished fossils and correspond with the numbers of the stations described. The boundary lines of the zones or belts have nowhere been observed directly; they are only approximations obtained from the location of the stations. The location of the fault, separating the Cambric and Normans kill beds, is taken from Walcott's map of the Taconic region (36).

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EXPLANATIONS OF FIGURES

PLATE 1

Fig.

1 A pebble of Trenton limestone with Pterygometopus callicephalus, Ampyx hastatus sp. n. and Climacograptus scharenbergi. x2

Lower Trenton conglomerate, Rysedorph hill, Rensselaer co. N. Y.

Paterula amii Schuchert

2 A partial cast of a pedicle-valve. x6

Normans kill shale of Mt Moreno near Hudson N. Y.

Schizotreta papilliformis sp. n.

3 A pedicle-valve. x4

4 Profile of the same. x4

5 A supposed brachial valve. x6

Normans kill shale of Mt Moreno near Hudson N. Y.

Leptobolus walcotti sp. n.

6 A small perfect specimen; showing fine concentric striation. Somewhat compressed. x6

7 An internal cast of a brachial valve; showing pedicle-groove, median septum and lateral scars. x4

8 The interior of a brachial valve, showing median septum and lateral scars. x6

9 A very young specimen, partially exfoliated; showing radiating striation of internal surface and pedicle-groove. x10

10 A strongly concentrically and radially corrugated specimen; the usual mode of preservation. x4

11 The interior of a similar specimen, showing pedicle-groove. x4

12 A shell, which instead of becoming corrugated, burst on compression. x4

Normans kill shale of Mt Moreno near Hudson N. Y.

Eopolychaetus albaniensis gen. et spec. nov.

Fig.

13 A specimen from the Rural cemetery, Albany N. Y. x4

Pontobdellopsis cometa gen. et spec. nov.

14–18 Specimens from the Rural cemetery, Albany N. Y. x3

Technophorus cancellatus sp. n.

All specimens from the upper Utica shale of Green Island, Albany co. N. Y. All enlarged. x3.

19 Small short specimen, showing basal margin

20 Surface sculpture of the same. x6

21 Sperimen with perfect posterior part

22 Partial cast, showing the impressions on both sides of the beak

23 Valve with nearly equally strong concentric and vertical lines

24 Largest specimen observed with somewhat different outline and stronger vertical lines

25 Surface sculpture of the same. x6

Plate 2

Ctenobolbina subrotunda sp. n.

1 Right valve. x17

2 Ventral view of the same. x17

3 Another valve. x17

4 Ventral view of the same. x17

Originals of figures 1-4 are from middle Trenton shale of Port Schuyler, Albany co. N. Y.

Ctenobolbina ciliata Emmons sp., var. **cornuta** var. nov.

5 Small left carapace. x17

6 Ctenobolbina ciliata. Larger right valve. x17

From lower Utica shale at Mechanicsville, Saratoga co. N. Y.

7 Ctenobolbina ciliata. Right valve

From the upper Utica shale of Green Island, Albany co. N. Y. x17

Ctenobolbina ciliata Emmons sp.

8 Internal cast. x17
Upper Utica shale, Menands, Albany co. N. Y.
9 Gutta percha impression of the same

Lepidocoleus jamesi Hall and Whitfield sp. x10

10 Trenton beds of Trenton Falls N. Y.
11 Middle Trenton beds at Port Schuyler, Albany co. N. Y.
12 Lower Utica beds, Mechanicsville, Saratoga co. N. Y.

Turrilepas (?) filosus sp. n.

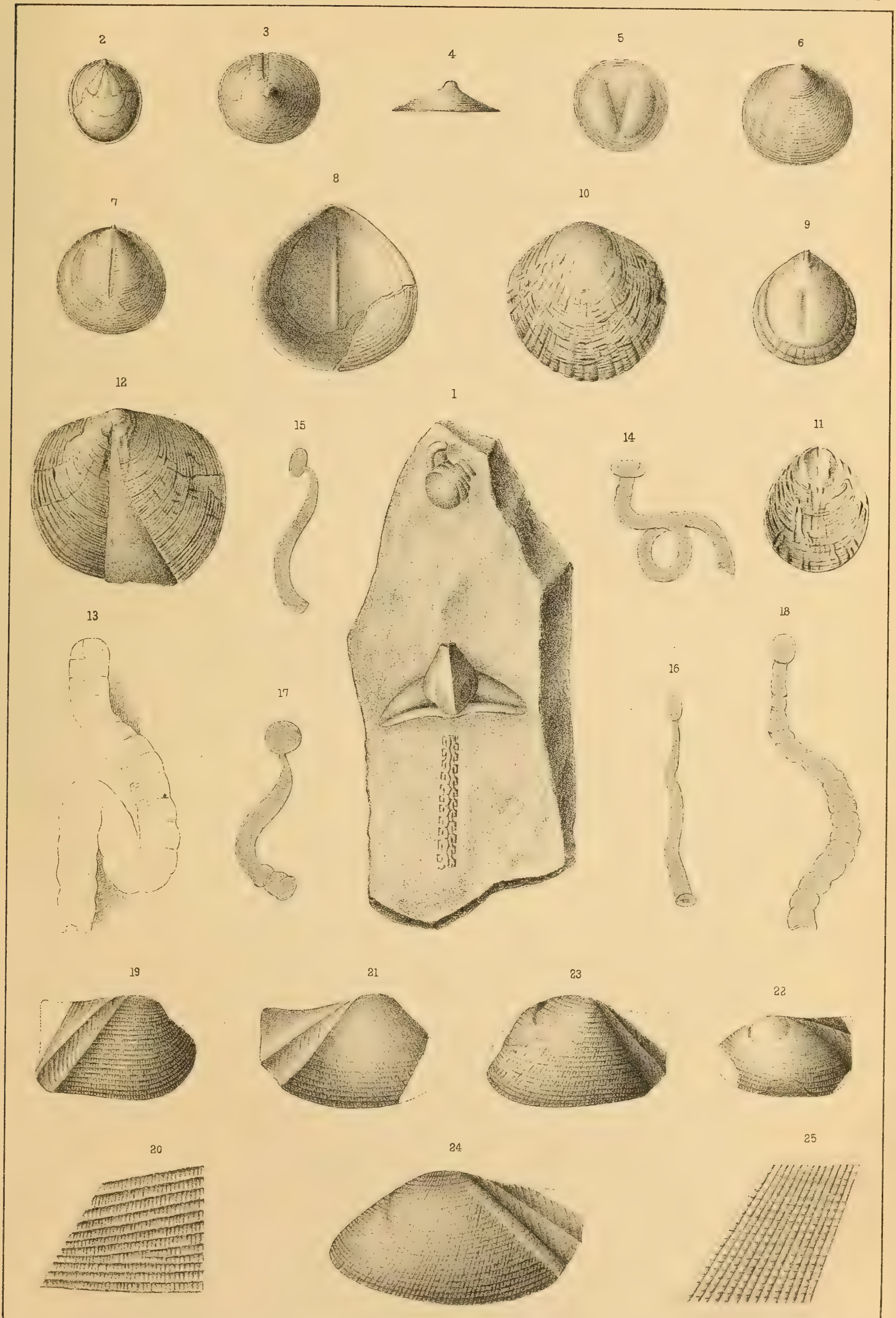
13 Smaller plate. x3
14 Enlargement of part of the same. x9
15 Larger plate. x3
Lower Utica shale of Mechanicsville, Saratoga co. N. Y.

Pollicipes siluricus sp. n.

All figures enlarged three times.

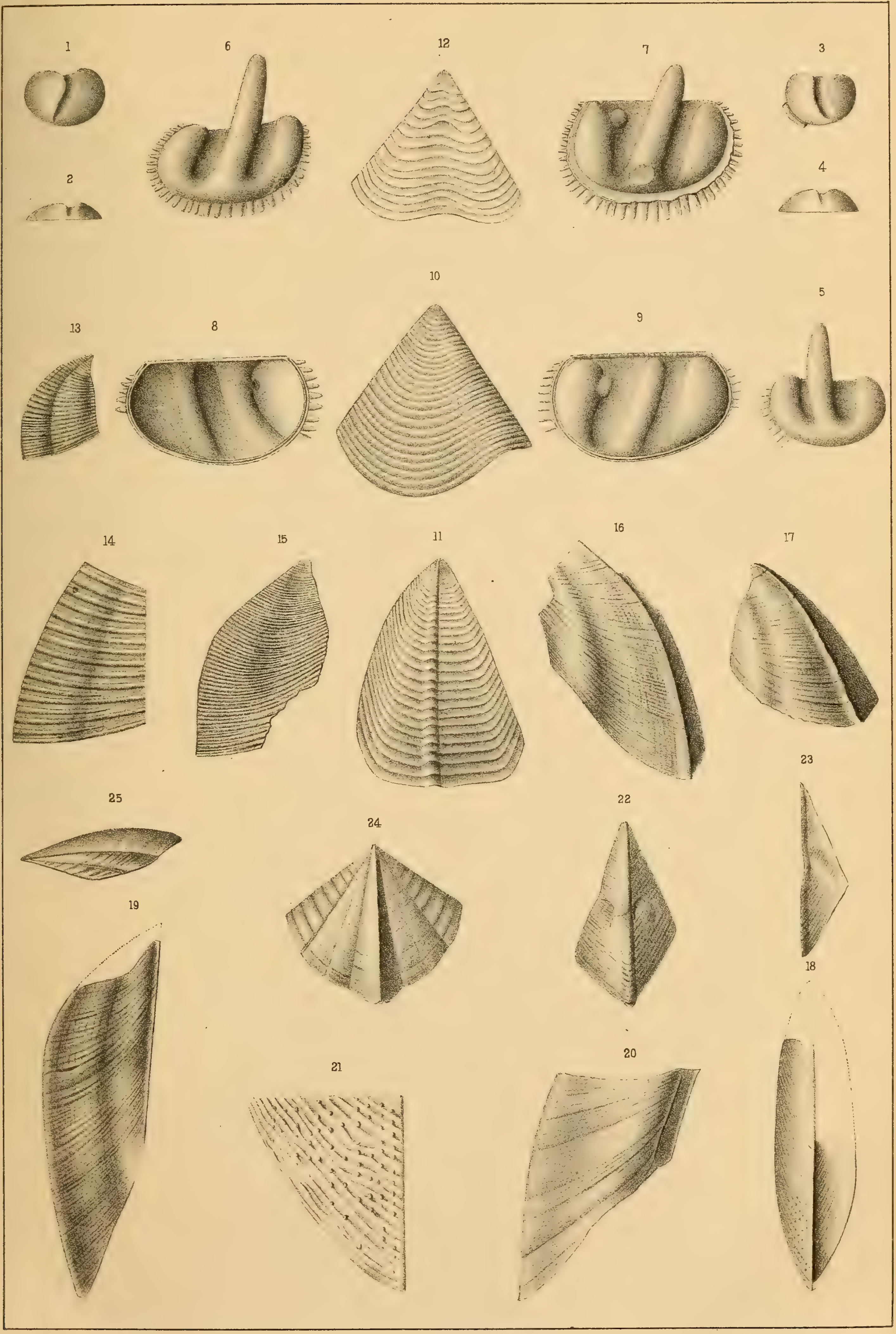
16 Left tergum
Upper Utica shale of Green Island, Albany co. N. Y.
17 A smaller and shorter tergum from the lower Utica shale of Mechanicsville, Saratoga co. N. Y.
18 Carina
19 Lateral view of larger carina. This valve has a prominent lateral ridge and narrow marginal border
20 Fragment of a carina with broad and low lateral ridge and broad marginal border
21 Farther enlargement of surface of original of fig. 18. x8
22 Rostrum
23 Lateral view of the same.
Originals of figures 18-23 are from the upper Utica shale of Green Island, Albany co. N. Y.
24 Upper latus, from a gutta percha impression. Lower Utica shale of Mechanicsville, Saratoga co. N. Y.

Bull. 42 N.Y. State Museum. Plate 1.



G. B. Simpson del. James B. Lyon, State Printer. Phil. Ast, lith.

"HUDSON RIVER" FOSSILS



G. B. Simpson del. James B. Lyon, State Printer. Phil. Ast, lith.

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The superior figures tell the exact place on the page in ninths; e. g. 520^3 means page 520, beginning in the third ninth of the page, i. e. about one third of the way down.

University of the State of New York

BULLETIN

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FREDERICK J. H. MERRILL *Director*

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CLAM AND SCALLOP INDUSTRIES

OF

NEW YORK STATE

BY

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ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1901

CONTENTS

INTRODUCTION

The growth of commercial interest in the natural resources of our country and the public appreciation of the importance of scientific knowledge in husbanding and developing these resources, have made it necessary for the state museum, in its relation to the public of New York, to give attention to all parts of the animal, vegetable and mineral kingdoms which contribute to the needs and comforts of our citizens. There being comparatively little accurate knowledge accessible to the public on the subject of the life history of the clams and scallops and the possibility of their cultivation, the director has been led to engage the services of Prof. James L. Kellogg, of Williams college, to study and report on the subject in which he is the acknowledged master.

While, in the brief space of one field season, it has not been possible to exhaust the subject, the following report is issued in the belief that it will meet the wants of many persons throughout the state.

FREDERICK J. H. MERRILL

Director

Albany N. Y. Dec. 1900

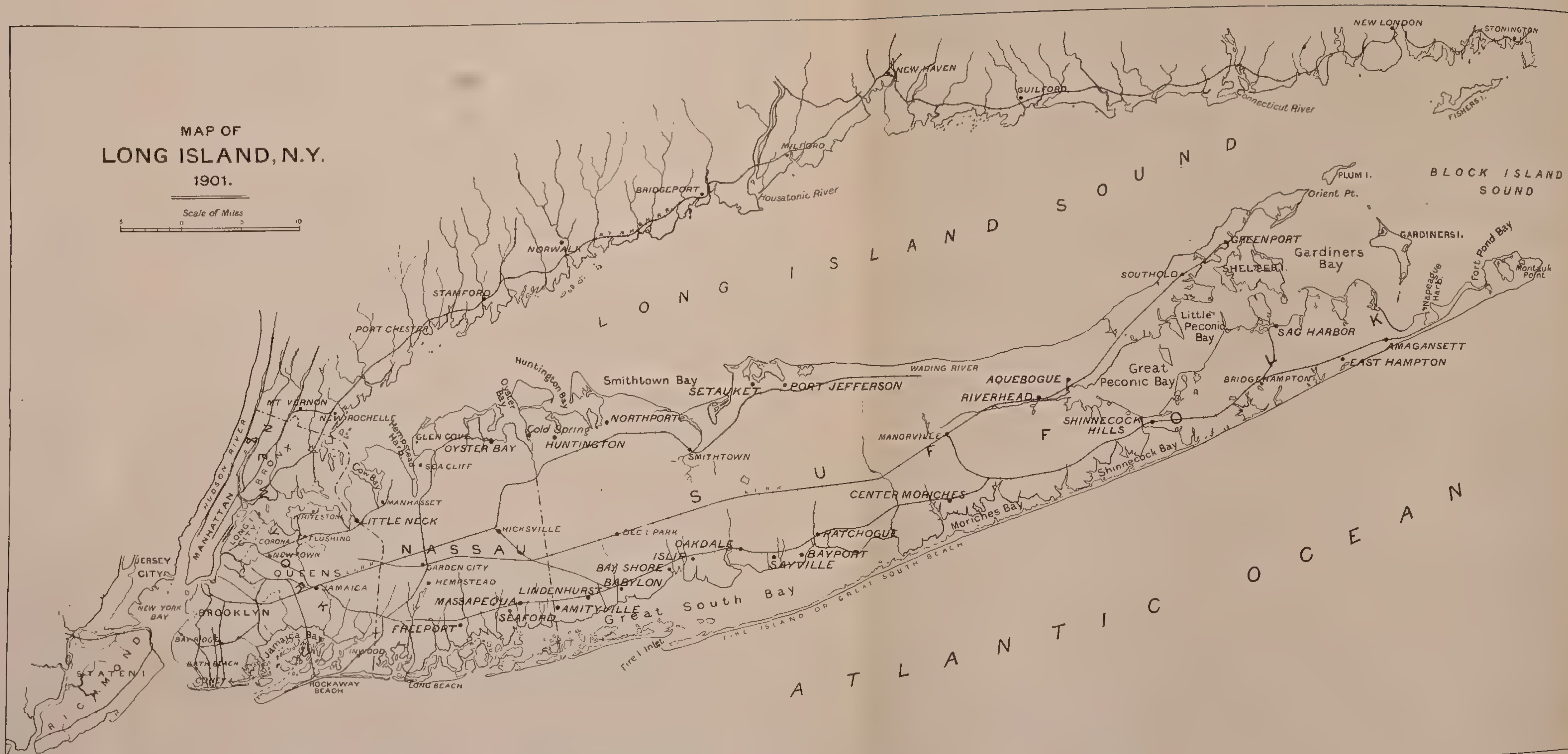
CLAM AND SCALLOP INDUSTRIES OF NEW YORK STATE

DEPLETION AND RESTORATION OF SUPPLY

The comparisons so frequently made btween the social conditions and habits of European peoples and our own, for many reasons are worthy of careful consideration. In Europe the ignorance of the masses in most regions is greater than in America. The greater part of the population is poor. Intercommunication amounts to almost nothing, and the simple needs and desires of a people remain what they have been for many decades.

In America everything is different. The aggressive methods of commercial enterprises, the form of government by the people, the migration into new territory, and popular excursions and expositions, have tempted even the most humble to more or less extended travel. The idea of a diversified life has become national. A knowledge of the social habits of one community has added to the desires of another. The entire country has become the most homogeneous of the nations of the earth, though made of the most diversified units. One portion has stimulated another till the whole has advanced rapidly. The art of living better has been practised by all, and the high-priced luxuries of yesterday have steadily become the low-priced necessities of today. The demand for a rare commodity increases its production, lowers its price, and again enlarges its demand till a certain balance of supply and demand has been reached, which usually brings it within the means of all.

There have been some cases, however, in which the demand has been met with such reckless indifference to future supply, that established industries have been threatened with destruction. In no


MAP OF
LONG ISLAND, N.Y.
1901.
Scale of Miles
LONG ISLAND SOUND
BLOCK ISLAND SOUND
ATLANTIC OCEAN
NEW LONDON
STONINGTON
NEW HAVEN
GUILFORD
Connecticut River
FISHERS I.
MILFORD
Housatonic River
BRIDGEPORT
NORWALK
STAMFORD
PORT CHESTER
MT VERNON
NEW ROCHELLE
HUDSON RIVER
MANHATTAN
BRONX
JERSEY CITY
NEW YORK BAY
BROOKLYN
QUEENS
NASSAU
JAMAICA
FLUSHING
CORONA
NEWTOWN
LITTLE NECK
MANHASSET
GLEN COVE
OYSTER BAY
SEA CLIFF
Hempstead Harb.
Cow Bay
Oyster Bay
Huntington Bay
Cold Spring
HUNTINGTON
NORTHPORT
Smithtown Bay
SMITHTOWN
SETAUKET
PORT JEFFERSON
WADING RIVER
HICKSVILLE
GARDEN CITY
HEMPSTEAD
FREEPORT
MASSAPEQUA
SEAFORD
AMITYVILLE
LINDENHURST
BABYLON
BAY SHORE
ISLIP
OAKDALE
SAYVILLE
BAYPORT
PATCHOGUE
Great South Bay
Fire I. Inlet
INWOOD
Jamaica Bay
ROCKAWAY BEACH
LONG BEACH
BAY RIDGE
BATH BEACH
CONEY
STATEN I.
RICHMOND
CENTER MORICHES
Moriches Bay
MANORVILLE
RIVERHEAD
AQUEBOGUE
Great Peconic Bay
Little Peconic Bay
SHINNECOCK HILLS
Shinnecock Bay
SOUTHOLD
GREENPORT
SHELTER I.
Gardiners Bay
GARDINERS I.
PLUM I.
Orient Pt.
SAG HARBOR
BRIDGEHAMPTON
EAST HAMPTON
AMAGANSETT
Napeague Harb.
Fort Pond Bay
Montauk Point
SUFFOLK

case has this been better exemplified, perhaps, than in the taking of marine food. The demand for salt-water fish and mollusks has increased at a great rate during the last few years. In all the smaller, as well as in the larger cities and towns of the interior, the demand for fresh mackerel has been added to that for the salted fish. Rich and poor alike have formed a liking for fresh halibut, cod, herring, smelt and shad. Even in a more marked degree has the public demanded the oyster, first in the can, then in "bulk", and finally in the shell. The secret of successful canning, put into practice soon after the civil war, led to the distribution of such food all over the Union. Salmon, oysters, lobsters and clams found a great market in this way, and the production assumed enormous proportions. But in most of these cases, the natural supply soon showed signs of failing.

In Chesapeake bay, probably the most favorable locality in the world for the growth of oysters, the natural beds gradually failed from excessive dredging. The simple method of transferring small oysters to bottoms where oyster food was abundant, though the conditions were not favorable for reproduction, were resorted to with great success about Long Island, and along the southern New England coast. The industry is still growing. In parts of Long Island sound, the "spat", or swimming embryos, "set" or attach themselves naturally, and oyster life in these regions has become much what it is on natural beds. Even the small oysters used in transplanting, are now taken from these beds, and the whole industry has become largely independent of the southern supply. While the conditions of growth are much more favorable in the Chesapeake, the laws of Maryland and Virginia offer little protection to the oyster "farmer", and a very great revenue is lost to those states. While the supply of oysters was at one time seriously menaced, intelligent methods of artificial propagation have permanently established the industry on the northern coast.

With some other forms of marine food this restoration will be much more difficult. It is never attempted in any case till extermination has become almost complete. Even with abundant material for his work, the culturist often finds it hard, or even impos-

sible, to control the young during its precarious early life till it reaches that stage of development where it is able to care for itself.

Everyone is familiar with the extensive and remarkably successful work of the United States and the various state fish commissions in the propagation of marine and fresh-water market fish. In many cases, the continued supply is probably directly and entirely due to the artificial hatching and judicious distribution of the young fish. These institutions have made it very clear that public moneys could not be better expended for the benefit of all classes of people than in their support. Their field is constantly enlarging, also, as one after another of aquatic food animals diminishes in number, and begins to disappear. If the fact were only recognized, that this threatened extinction of forms really is occurring, these commissions and similar institutions would receive much greater support in the form of legislative appropriations. More money for carrying on the work already attempted is urgently needed, and more still will be required as the field of labor enlarges. At the same time, it is money most profitably invested for rich and poor alike.

The reestablishment of a destroyed industry which depended on organisms living and reproducing in a natural state, is usually slow. No one would expect a community depending on wild cattle for its beef to consider the future seriously till the supply was nearly exhausted. Men seldom look far ahead in such matters. When the extinction is practically accomplished, they cast about for a remedy. The close season suggests itself. But, while waiting for the few remaining animals to increase to the necessary number, man is necessarily deprived of food. Even if the flocks quickly recover their numbers, because natural conditions for their growth are favorable, the same decrease and destruction is very likely to recur.

The point is that, when an organism—animal or plant—is largely used as food by man, nature is most often unable to keep up the supply indefinitely, and man must breed and cultivate the desired form under controlled, and more or less artificial conditions.

In our illustration, the habits and needs of the animal—specially the need of food—must be determined, in order that, under confinement, a maximum rate of reproduction may be obtained. In ad-

dition, an increase in the quantity and an improvement of the quality of flesh are aimed at, though this is brought about in higher animals by a careful selection, in many successive generations, of breeding individuals. The whole industry must be built up on an artificial basis, and the first step is to discover in detail the habits and needs of the animals in the natural state.

The same is true of marine food animals. The history of the reestablishment of their supply shows that in every case almost complete destruction has been threatened before any move has been made to improve matters. While a more or less extensive close season operates favorably in some cases, it usually fails permanently to correct the evil condition. While in operation, it suspends the supply altogether. At times it seems to be a necessity in order to prevent complete annihilation; but, if artificial methods were developed early enough, it would not be necessary.

Food supply and proper environment are obviously more obscure in the case of marine than of terrestrial forms, and in many instances are almost entirely unknown. It is surprising to find how true this is even with food animals with which we have long been familiar. But before artificial methods of culture can be developed, it is of course necessary to know the animal's habits and its relations to its surroundings, and to understand all the necessary conditions thoroughly. It is the necessity for this preliminary scientific work that is probably least understood by the public. This work is sometimes slow, and not always productive of economic results, but it is always the necessary first step in developing culture methods.

MYA ARENARIA

Soft clam, or long-neck

It has been, and still is assumed that nature is so lavish in her supply of certain animals that man is unable greatly to diminish their number, much less to cause actual extinction. This is a dangerous belief, but still very common. The lesson of the buffalo and wild pigeon, whose countless multitudes have been known to men of this generation, is not heeded. Scores of similar cases apparently have not lessened man's presumption.

For many hundreds of miles along the north Atlantic coast, it has always been possible to find our common long-neck, or soft clam. It has long been used extensively in the market, and has been dug for so long a time that the supply was apparently limitless. 10 years ago it perhaps would have been impossible to find anyone who believed that a time would ever come when this area should become practically barren. Even at that time, clams were not so abundant as formerly, but the area was great; clams could be taken almost anywhere. They were not everywhere numerous, but in some localities the supply seemed to be without limit. But suddenly the unexpected happened. During the last three or four years, the supply rapidly diminished, and the industry became almost completely paralyzed, excepting in Maine and certain parts of Long Island. Immense flats, long productive, now bear practically nothing. The few remaining regions where clams are dug of course are taxed to such an extent that they can not long maintain themselves. The state of Maine has recently (1899) recognized this fact, and has made the busy summer months (June 1 to Sep. 15), a close season, in which clams may not be canned, exported or sold. While the soft clam has disappeared from many parts of Long Island, there are still two or three localities where they are fairly abundant. These regions, however, not only are called on to yield an increasing number, but they are confronted by a new and peculiar problem in the relation of the clam and the oyster interests which will be described presently. There can be no question that this ruin of the clam industry on our Atlantic coast has been accomplished by excessive digging without corresponding efforts to increase the supply by culture methods. The falling off has been noticed for more than 20 years, but the final disappearance came suddenly.

It must be remembered that the record of market sales does not necessarily indicate the real abundance of the forms considered. A greater demand means a greater production till the limit is reached. An increasing demand, with its higher prices, means that more men are collecting the supply, and with increased energy. It is very evident, then, that the final exhaustion will come suddenly, and

that the record of the market does not indicate in advance just when that evil day shall appear.

It is true, however, that the demand for clams and scallops has been increasing steadily for many years. To our personal knowledge, several towns and smaller cities in the Mississippi valley which formerly consumed a small number of canned clams, have more recently demanded, during the winter months, larger and larger quantities, not only in cans, but also in the shell. The demand has grown rapidly in recent years with the knowledge of their value as a food. Even scallops, sold fresh in bulk, are finding a market farther and farther from the shore.

From the fact, then, that the soft clam has been steadily demanded in increasing numbers for some time past, the following tables will be instructive. They indicate the market supply to 1892, and are taken from the report of the United States fish commissioner for 1894. The item referring to the supply from Rhode Island in 1898 is taken from a paper by Dr A. D. Mead in the 13th annual report of the commissioners of inland fisheries of Rhode Island. The interesting figures covering the Maine supply for 1898 were recently received from the able commissioner of sea and shore fisheries, Mr A. R. Nickerson. They show an enormous increase in the supply over any previous year of which we have any record, and thus show that the previous figures gave no adequate idea of the actual supply. Many factors enter into the explanation of this increase in the number of clams marketed, the most important of which is the fact that the sudden decrease in the supply from other New England states left Maine alone to answer the demands of the general market. That her clam beds are already suffering from the enormous drain is shown by the fact above mentioned, that in 1899 her legislature passed an act prohibiting the sale of clams in any form from June 1 to Sep. 15 in each year.

Emphasis must be laid on the fact that these figures do not really indicate the abundance of clams on the beds at any time. Without the figures of the Maine supply for 1898, we should get an entirely erroneous idea of the conditions in that state. The sales in Massachusetts and Connecticut since 1892 would undoubtedly show

a great decrease. We were not able to get the figures covering these last eight years, or for any one of them, in these states.

Soft clam supply by states

Maine

	Bushels	Value
1880	318 383	$101 808
1887	608 780	228 490
1888	600 675	227 665
1889	595 105	200 761
1892	416 806	157 431
1898	1 109 936	393 577

New Hampshire

	Bushels	Value
1880	17 960	$8 980
1887	280	140
1888	300	150
1889	300	150
1892	1 050	975

Massachusetts

	Bushels	Value
1880	158 626	$76 195
1887	230 659	121 202
1888	243 777	127 838
1889	240 831	137 711
1892	191 923	133 529

Rhode Island

	Bushels	Value
1880	53 960	$48 564
1887	25 825	25 030
1888	30 825	30 030
1889	33 375	32 475
1892	33 950	45 222
1898	15 015	20 569

Connecticut

	Bushels	Value
1880	75 000	$38 000
1887	26 735	25 370
1888	26 575	24 270
1889	26 360	24 900
1892	23 780	25 320

It will be noticed that, with two exceptions, we have in these tables no reference to sales during the last eight years. No serious attempt has been made to collect data showing market sales in New York, for, as explained, such a record does not show conclusively the productive capabilities of the beds. The only way to obtain a knowledge of this is by visiting the clam flats and beaches. Since the summer of 1898, a large part of the shore from the state of New Hampshire to the city of Brooklyn has been personally explored, and while Maine, for clearly understood reasons, has increased her market supply—not her resources—at almost every other point on the coast, the soft clam industry has been practically ruined.

Soft clam supply in New York

The industry in this state has been extensive. It became apparent that the supply of hard and soft clams, and of scallops, was decreasing, and at the invitation of Dr F. J. H. Merrill, director of the New York state museum, a personal inspection of the entire coast of Long Island was attempted during the month of September in the present year (1900), with the view of determining the present condition of the beds. Though it was necessary that this examination should be a hurried one, its results show conclusively that, except in one or two localities, the accomplished depletion of the New England coast is being repeated here.

A reference to the appended map of Long Island will show at its eastern end very extensive bodies of water in Peconic and Gardiners bays. The surrounding shores of both seem to be wonderfully adapted to the growth of the soft clam. According to the reports of clam-diggers in that region, even so far inland as at Riverhead, thousands of bushels dug at the west end of Peconic bay are marketed there every winter. It is maintained that recently there has been a noticeable diminution in the supply, but that it has not as yet become alarming. The shores of Shelter island, except on its northern side, have produced many clams. The supply here also is said to be falling off rapidly.

Shelter island, like the greater part of Long Island, supports an increasing summer population, which is already very large. In

recent years, these visitors, during their stay, probably have caused an increase in the demand for clams. It is a curious fact, however, that, while in New England the soft clam is used extensively during the summer months, in the popular clambake, there is very little demand for it anywhere on Long Island during that season. There the hard clam, or "little-neck," is in favor, and is used, too, in great numbers. It is probable, then, that on no part of the island does the influx of summer residents greatly stimulate the digging of the soft clam. However that may be, clams are certainly being dug much too rapidly in this region.

On following the coast eastward from Sag Harbor, to Fort pond bay, many small bays and inlets appear which are among the most favorable localities on the entire coast for the growth of the soft clam. Such a place as Napeague harbor, for example, contains a supply so great that it has been regarded as being inexhaustible. Comparatively few clams from this part of the island are sent to New York. Very many are marketed at New London and other New England centers for distribution. A great number, also, are used for bait by fishermen. It was stated that one vessel recently was able to secure at Napeague about three hundred bushels in a short visit, for such a purpose, and that this amount has been repeatedly taken. If such reports are true, the supply is still great; but at all points on this coast it is the almost universal testimony that the beds are being depleted and ruined at a surprisingly rapid rate. This condition has come about during the last two years, and is causing great concern. Measures should now be taken, before there is an actual destruction of the industry here, to conserve the supply of this remarkably productive region. With a little knowledge of the life history, the habits and needs of the clam, with little labor and a small outlay of capital, this can be accomplished easily, as we shall attempt to show later.

On the south side of the island, from Montauk point to Rockaway beach, is a straight reach of sand on which the surf continually rolls. On this exposed sea side, the conditions are nowhere favorable for the growth of either the soft or hard clam. The sand, however, forms a great spit which shuts in several large bodies of water, leav-

ing inlets here and there at rare intervals. In many parts of these bays the hard clam, or little-neck, was formerly very abundant, as will be shown presently, but, because there is very little tide, beaches and flats are not enough exposed to allow the digging of the soft clam. It is known that in some places this form lives below the low tide mark. There are such beds in the Great south bay, but, as the creatures are burrowed into the bottom from six to 12 inches, and even deeper, their capture under water becomes a laborious process, and is seldom resorted to. In Shinnecock, Moriches and Great South bays, then, comparatively few of the soft, or long-neck, clams are dug for market, though more of these forms than is ordinarily supposed may exist in the mud below the low water mark.

There is one locality on the south side of the island where Mya is apparently abundant, and is dug in great numbers. That is Jamaica bay, with its shallow water, and its relatively great rise and fall of tide, which alternately covers and exposes a large area of mud flats. Unfortunately, lack of time prevented a thorough examination of this bay. Many residents of its shores agree in stating that it contains an abundant supply of soft clams, many of which are sent to the New York markets, eight or 10 miles away. It is said that there are places on the flats where it is possible for a man to dig five or six bushels in a fair low tide. Assertions of this kind should be carefully verified before being accepted.

This bay, situated at the door of the New York market, a bay with extensive flats and rapid currents, affording most favorable conditions for the growth of clams, seems to be a very valuable property; and if the few reports we have about it are true, it should be carefully guarded and protected against that depletion and ruin which comes from excessive digging, and which has recently visited similar and equally extensive flats. Because the supply has apparently continued till now, and may seem to be inexhaustible, there is no reason why the beds may not become as barren as those at Duxbury and at Essex in Massachusetts. At one time in the latter town, 100 men steadily obtained from $2 to $5 a day by digging the soft clam. Today there are not 10 men engaged in the work, and, with a greatly increased price for the product, they

obtain from 50 cents to $1.50 a day for their labor. Practically no clams are allowed to grow to a size suitable for market, so closely are they sought by the diggers. The ruin of the great Duxbury flats is just as complete. These lessons should certainly be heeded by those who still possess productive clam flats.

Passing to the north side of the island, there are several arms of the sound, at its western end—Cow bay, Hempstead harbor, Oyster bay, Huntington bay and Smithtown bay—in which the history of the clam industry is very much the same. Several years ago, these extensive shores bore the soft clam in great numbers. The history of the New England coast has been repeated here. There was for many years a gradual diminution in the number of clams. During the past two years, the falling off in the supply has been very great, and the beaches are now becoming practically barren. No other part of the coast of Long Island seems to be in a more dangerously depleted condition. As in all similar cases, this is certainly not due to a change in the nature of the bottoms or of the waters of these bays, but has resulted solely from excessive digging. A close season extending through the summer months, is in operation, but it seems to have had little influence in checking the decrease.

To the east of Smithtown bay, the shore is bold and little broken by inlets, and here neither the soft nor the hard clam has ever been abundant.

From this hurried examination of the shores of Long Island, it appears that many extensive areas offer extraordinarily good natural conditions for the growth of M y a, the soft clam. The supply, also, is now much greater than on the New England coast except in Maine. This is fortunate; for, if immediate steps are taken to prevent it, the destruction of the industry may be averted, and the supply increased at a time when the demand is rapidly growing and prices are rising. The regions which, under these circumstances, first introduce culture methods are to derive great benefit from the enterprise, and, having obtained the market by means of this advantage, should for some time be able to hold it. This fact is recognized by one New England state, which has made appropriations that are available for a practical inquiry into the possibilities of clam culture.

Our chief conclusion must be that in most localities along the shore of Long Island the supply is now failing rapidly, and, unless these methods of artificial propagation are introduced, must soon fail completely.

Life history of Mya the soft clam

I have briefly traced the condition in which we find the soft clam industry at the present time, not only in New England, but in New York. We may now consider the question of a remedy for the disagreeable situation which confronts us. If we continue to depend simply on the natural powers of reproduction and recuperation of this form, we shall certainly soon see the end of the large supply on which we have so long depended. Fortunately there seems to be a way to meet the difficulty, and not only recover the original supply, but produce one even larger.

It has already been shown that, before it is possible to develop culture methods for the artificial rearing of any form, it is necessary to possess a knowledge of its habits, the character of its food, its relations to its enemies—in short, as complete an account as possible of its life history.

It is a curious, but common experience to find that we still lack such a knowledge of some of the most familiar animal forms. In a general way, we have for many years known something of the structure of the common clam, and something also of the character of its food. Till 1898, however, almost nothing whatever was known of its life history, including the limits of the breeding season, the habits of the young and the relations of the animal to its surroundings. In that year a study of the form was made in order, primarily, that the knowledge obtained might be applied in the elaboration of methods of artificial propagation. Since that time, many experiments, the results of which are not yet published, have been carried on for the United States fish commission, and have shown that the culture of the soft clam may easily and successfully be accomplished on a large scale. It may be noticed that we are still without knowledge of the life histories of the hard clam and the scallop, though the present necessity seems to demand it.

What we know of the life and habits of Mya may be summarized briefly.

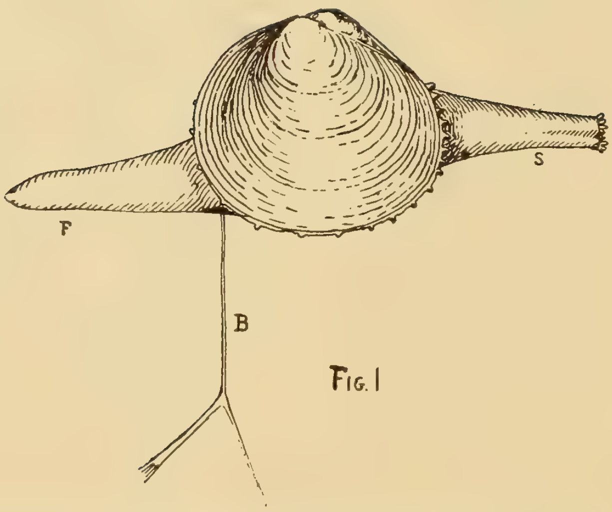


Fig. 1

Fig. 1 Drawn from living clam .4mm (less than one fiftieth of an inch) in length. S, siphons, two tubes, one of which conducts water bearing food and oxygen to the body within the shell, the other conducting a stream containing waste matter to the exterior. F, foot, the organ of locomotion. B, byssus, a delicate thread for attachment, which is not present in the adult.

The breeding season extends through the months of May, June and July, though in this last month comparatively few young are produced. The sexes are separate, and the ova, or egg cells of the female, as well as the spermatozoa, or sexual cells of the male, are extruded directly into the water. Here a single spermatozoon unites with an ovum, the two becoming a single new cell. This cell multiplies and eventually builds the body of an embryo. By means of delicate, hairlike projections from the body, which lash very rapidly in a definite direction, the creature is enabled to swim. The details of these early stages in the clam are not known.

We do know, however, that eventually the swimming embryo develops a minute shell similar to that in the adult, in that it is made up of two pieces covering the right and left sides of the body.

During the continuance of the swimming period the creature may have been carried, not only by its own efforts in swimming, but also by tide currents, to some point far removed from that where its life began. A single pair of clams may give rise to millions of embryos during one season. The great majority of these are lost, but a few, losing their swimming organs, happen to settle in some locality which is favorable for their future growth and development.

From this time, their history has been followed in some detail. The small clams, when they cease swimming, are still minute in size. Many individuals only .4 of a millimeter in length have been observed, and their bodies are so small as to be indistinguishable to the unaided eye from the smallest grains of sand on which they may have fallen.

In its general outline, this small clam is very different from the adult, in that its body is very much rounded, instead of being elongated (fig. 1). As it grows, however, its shell elongates, but, at the same time, the two prominent points of the shell, or umbones, are shifted relatively farther forward, as in fig. 2; and then, eventually, they come to lie nearly in the middle of the shell on its upper side, as in the adult clam.

A glance at fig. 1, drawn from an individual .4 of a millimeter in length, will show two conspicuous structures projecting from the margins of the shell. One of these (s) is the pair of filmy siphons—

the "neck", or "snout", of the adult. There are here two separate tubes, one of which conducts water to, and the other from the body within the shell. These organs are long and fleshy in the adult, and reach from the clam's body in the mud up to the water above. In the young they are relatively small and very delicate.

The other projection is the so-called "foot" (f), the organ of locomotion. It is here relatively much larger than in the adult, and by its peculiar thrusting and retracting movements, the creature creeps on the surface of foreign bodies, or digs into the sand.

One of the most interesting features of the life history of Mya is the fact that from a special gland near the base of this foot, a long, nearly transparent thread, the byssus (b), is produced, which is attached to such bodies as stones or pebbles or to floating objects in the water. It acts as an anchor thread, and undoubtedly is developed that the light, minute body of the very small clam may not be floated about by water currents. It completely disappears before the adult condition is reached, and is developed very soon after the little clam ceases swimming.

These small clams are restless, and apparently always desire to creep about. Though the threads are many times the length of the body, they allow of little movement. From time to time the thread is cast off, for, once attached at its ends to sand grains (s. g. in the figure) or other bodies, it can not be loosed. The clam then slowly creeps about by means of its foot, but soon spins a new thread, at the same time attaching it by its free ends. This may be repeated many times, the clam never remaining for any length of time unattached.

Very early the young clam manifests the digging instinct. Being a helpless creature, and subject to attack by enemies (notably small starfish), it is necessary that it should cover itself in the bottom as soon as possible. When but little more than a millimeter in length, the creature thrusts its tiny foot down between the sand grains in a tireless effort to obtain a lodgment. This can not be accomplished, however, for the light body is still not much larger than the sand grains which it attempts to displace. When a length of two or three millimeters is reached, the body is sometimes partially or per-

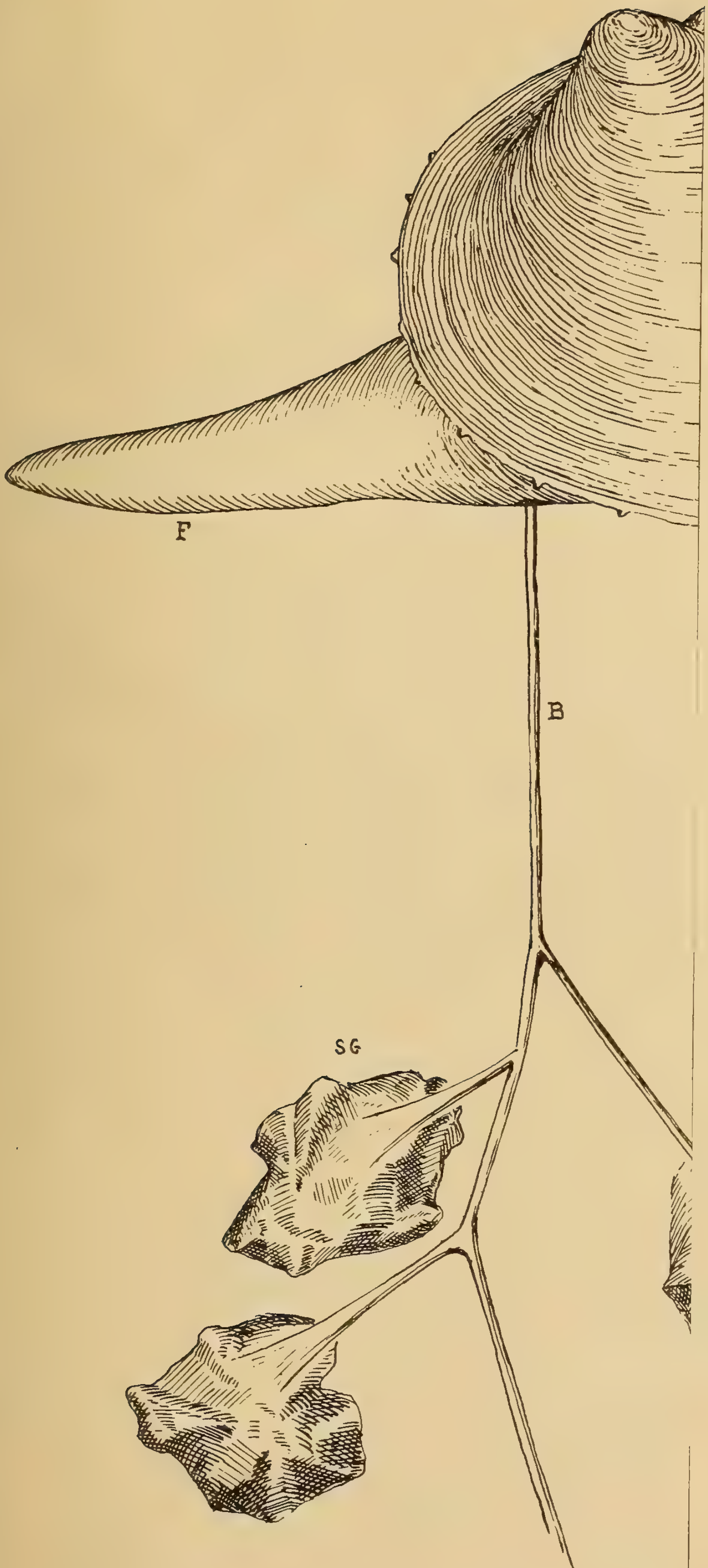


Fig. 2 Drawn on a much smaller scale than fig. 1, from a c
S, G, small sand-grains to which the byssus is attached. Ot

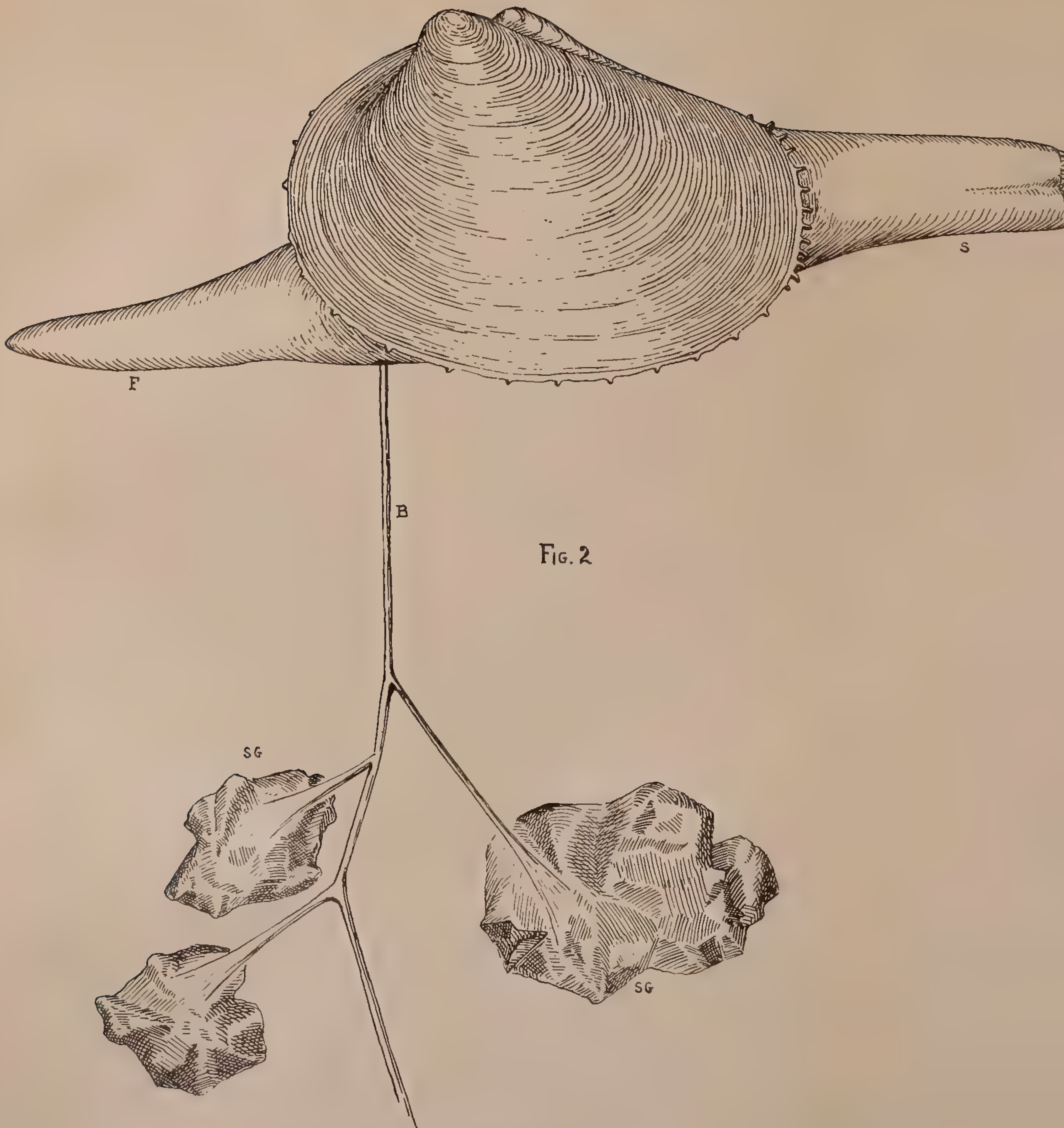


FIG. 2

Fig. 2 Drawn on a much smaller scale than fig. 1, from a clam 2.5mm (about one tenth of an inch) long, taken from its burrow. S, G, small sand-grains to which the byssus is attached. Other reference letters as in fig. 1.

haps wholly covered, if the sand of the bottom be very fine. When a length of 6 or 7 millimeters is reached, a clam is able to dig below the surface on any bottom, and is able to cover itself with much celerity.

As soon as burrowing is possible, the young clam remains buried most of the time, reaching up to the water with its siphons, by means of which it obtains its microscopic food (chiefly diatoms) and the oxygen used in breathing, both of which are suspended in the water. A very interesting fact is discovered when these burrowed clams are dug up and examined. It is that here also the byssus fiber is thrown out and attached firmly to the surrounding pebbles and sand grains, in order that the clam may not be dislodged from its shallow burrow by waves or currents and carried away, or perhaps thrown up on the beach to perish.

Even in its burrow, the small clam exhibits a strange restlessness. It repeatedly casts off the byssus from its body, digs out to the surface, and creeps away, only to go down and again attach itself.

As the clam becomes larger, this wandering habit manifests itself less frequently. It asserts itself, however, till the creature is 12 or 13 millimeters long (about half an inch). An individual of this length still possesses the byssus, but at about this time digs down to remain permanently, and the byssus gland is absorbed, and never reappears. It is simply an organ of the young, and, while in functional activity, performs a very important office, as has been shown. The clam now, except from accident, always remains buried, only reaching up to the surface by its siphons, which soon become long and heavy. If it should be dug up, it is still able to bury itself again, though the foot becomes relatively small. Large clams perform this act of burrowing with very great difficulty.

These, briefly stated, are the chief points of interest in the developmental history of M y a. We may now notice a few facts concerning the "set" of young clams.

The number produced varies greatly in different seasons. The reasons for this are complex and at present not well understood. Whenever a full "set" of clams occurs along the shore, the young are found to occupy certain restricted regions in vast numbers. This

is usually just below the low tide mark and only where currents are comparatively swift. In such favored localities, they often accumulate in such numbers as to touch each other, being crowded as close as they can stand. These are small clams, only large enough to dig beneath the surface. The swimming embryos settle to the bottom both above and below this line.

The subsequent history of their existence in this restricted locality just below the low tide mark is interesting. As they become older and larger, they die on the surface and in their burrows from lack of food.

Beds between tide-lines are recruited only from forms which happen to settle in them.

We thus have during the months of June and July a multitude of small clams which have settled just below the low tide mark in certain restricted localities near clam beds. They are engaged in a severe struggle for existence among themselves, and, if allowed to remain undisturbed, the great majority die. They are, however, only in great numbers during certain seasons. Not in every succeeding year are the numbers great. Observations have not been continued long enough to determine how often, on an average, we may expect a " set " such as was witnessed in 1899 in certain parts of Buzzards and Narragansett bays. Clam-diggers, however, generally state that it occurs every third or fourth year, though, so far as can be ascertained no one has observed the phenomenon closely.

With these data, and some additional points which will be mentioned as we proceed, we may induce certain conclusions which are of value in formulating a plan for clam culture.

1 **Artificial fertilization.** By cutting open the sexual glands of male and female and causing the sexual cells to mingle in a dish of water, fertilization can be effected easily in the case of the oyster. Apparently it is accomplished with difficulty in Mya, but it has been done, and embryos are brought into existence at the will of the operator during the breeding season. But all attempts to control and rear oyster embryos to the adult condition—at least in numbers—have failed. There is every reason to believe that they would fail in the clam. This point, then, may be passed over as being

impracticable, and in the case of the clam, the operation is certainly quite unnecessary, as will be shown.

2 **Tenacity of life in the young clam.** The adult dies quickly in aquariums in warm weather. Very small individuals are, on the contrary, very tenacious of life. They have been carried in an open bucket from Narragansett bay to Buzzards bay in the hottest days of summer, and, though the water in which they were transported became very warm, they had suffered no apparent injury when placed once more in cold water. Not only so, but many, subsequently kept in shallow dishes without change of water, lived for days after a bacteria zoogloea had formed over them. For purposes of planting, then, the young clams may be transported easily for long distances without harm.

3 **Effect of water of differing degrees of salinity.** Fortunately for the clam culturist, the adult M y a will thrive not only in water which is very salt, but also in that which is nearly fresh. At Woods Hole (Mass.) for example, where the salinity is great (about 1.024), many recent experiments have shown a remarkable rate of growth. Other regions have been observed where the degree of salinity is seldom more than 1.005, in which clams seemed to flourish equally well.

Not only is this true, but acclimatization is not necessary when a change is made from one locality to another. Many recent experiments, besides the one just referred to, show this to be true. Many, if not most, marine animals are very sensitive to changes in the saltness of the water. The fact that the soft clam is not so affected, even by a sudden transfer, is not only interesting of itself, but its significance in the development of a method of clam culture is evidently of the greatest importance. Many clam flats, today practically barren, may be planted with clams taken from any other locality without reference to the salinity of the water in either place.

4 **Character of the beach or flat favorable for growth.** M y a grows well in soils of many sorts. Some of the best clam flats are composed largely of sand. Flats also often contain quantities of fine mud. These of course are more favorable for planting because

they may be dug easily; but, when other conditions are good, clams grow equally well in gravelly or even rocky beaches. They are frequently found, also, thickly set in hard clay.

Unpublished observations show that certain definite conditions of the soil must be present in all these cases, and these conditions, too, are exact. Clams will not grow on every bottom; but enough has been said to indicate that soils of various kinds often are suitable for growth. One of the things about which the clam culturist need concern himself least is a bottom on which to plant his clams.

5 **Collection of clams for planting.** In almost all cases this should be an easy matter, and this fact is, of course, one of the greatest importance. It is one of the greatest difficulties encountered in oyster culture, and practically does not exist here.

On larger clam flats and beaches, great numbers of mature clams usually exist among the thatch plants. These are undisturbed on account of the difficulty in digging them. They give rise to many embryos which eventually appear in favorable localities in great numbers. Extensive flats always reveal patches of bottom, sometimes covering acres, where clams one or two inches long are packed too closely to grow, except at a very slow rate, from lack of sufficient food. When these small clams are dug and scattered over a larger area, they grow with great rapidity. Clams from these crowded beds may be had at any time of the year.

In addition to this supply, there appear in certain seasons great numbers of small clams below the low water mark. They are so closely crowded that, on those beds that have been studied, nearly all seem to die before the end of the summer. Though they appear only in certain years, and then on restricted spots, where currents are swift, their numbers are so great that they can be gathered from the surface almost in a solid mass and spread over large tracts. As has been shown, they are tenacious of life, and, when under water, will cover themselves in four or five minutes if conditions are favorable.

Observations extending over a considerable coast line, the details of which can not be given here, indicate that little trouble would be encountered in obtaining abundant material for planting.

6 **Rate of growth.** In developing methods of culture, nothing could concern us more than the rate of growth. The oyster reaches a marketable size in three or four years. In other important respects we find that clam production is much easier than oyster culture. It requires little labor and less capital. But what about the length of time required for clams to reach a marketable size?

We may answer with much certainty that it is *not more than half as long a period as in the case of the oyster.* We make the statement in a general way. Under varying conditions, an oyster or a clam may grow fast or slowly. There has been a general belief that this variation in oyster growth is a matter of food. The belief is probably well founded. Very little is known of the relation existing between growth and the food supply in marine animals. Much recently acquired evidence shows that, to a certain limit, which is a wide one, the clam's growth increases with an increase in the amount of food. Its position in reference to water currents, then, has much to do with the rate of growth. However, it is perfectly safe to say that, on an average, clams increase in volume twice as fast as do oysters.

Recently many experiments have been made under various conditions, showing just how rapid this increase actually is in Mya. We may cite a single example, not at all an extreme one, in which a clam half an inch long became one and a half inches long in two (summer) months. Under specially favorable conditions, clams probably may reach a fair marketable size in one year from the time when their life begins; while clams which have lived for two years, in almost any clam beach, if not too closely crowded, should certainly be large enough to bring high prices.

7 **Legislation.** Culture methods, we must conclude, are in themselves simple and easy of application. There should be no difficulty in reclaiming depleted flats, if indeed they may not be made to yield more than when in the most flourishing natural state. At the very least, ground still productive should be prevented from becoming barren.

But there is one serious difficulty which threatens to defeat all efforts at clam culture. That is in regard to the control of clam ground. I have elsewhere discussed this matter, attempting to show

the futility of a close season, and expressing the opinion that the lease to individuals is the only way by which this industry can be established. And, when the lease is issued, also, it is absolutely necessary that state—and not merely local—protection shall go with it.

To bring this about, many state and local laws must be repealed, and new and adequate ones formulated, passed, and *enforced*. All of which seems to the ordinary observer to be an almost impossible task.

That one of the north Atlantic states in which popular sentiment is aroused to the extent of bringing about these changes is certain to receive immense benefit from the effort.

VENUS MERCENARIA

Hard clam, or little-neck

In tracing the present distribution of the little-neck clam about Long Island, we reach essentially the same conclusion as with Mya. In many localities where it has been taken most abundantly, the failure has become alarming.

At the east end of the island in Peconic bay and in the region about Sag Harbor, the form still seems to be relatively abundant. This entire region, where Mya also abounds, is apparently an extremely rich one in its production of Venus. It is not possible at present to form an estimate of the annual production in these waters. We can only state that several centers are reported to ship tens of thousands of bushels every year. It is the general belief, however, that over the entire area the hard clam has been decreasing rapidly during the last two years. Other beds on the island, just as extensive as those in Peconic and Gardiners bays, are almost destroyed, but very fortunately the supply is still great here.

On the south side of the island, Shinnecock and Moriches bays have never produced many clams. The Great South bay, to the west of them, however, has the remnants of a hard clam industry with an eventful history. The clam supply from Patchogue to Freeport has been enormous. Almost all of the intermediate towns have had an extensive interest in clam tonging. The story of one of these is more or less typical of all.

Opposite Fire island inlet is the town of Islip, which has always been the center of the industry in the bay. Soon after the civil war, a factory for canning clams was established here. After struggling for several years to perfect the process of canning, and to obtain a market, the business grew to such proportions that 400 bushels (10,000 cans) of hard clams were canned daily. This output continued for years, clams being brought from all parts of the bay. About five years ago the supply began to decrease. Two years ago it became impossible to obtain clams, and today very few are canned there. The demand had steadily increased, and is now greater than ever. In order to keep its business, this company established another factory in one of the southern states.

The markets at Babylon, Amityville, Massapequa, and Freeport had also been quite extensive, but all report the same very recent failure of the little-neck in the Great South bay. As this region had supplied so great a market, the result of course is serious.

To the unprejudiced observer, it seems as if the enormous drain on the beds must in great part account for the ruin, but it must also be said that the growth of the oyster industry in the bay has had much to do with it. This point will be considered later.

In Jamaica bay, the little-neck is said to be abundant still, but in the short time at our disposal, it was not thoroughly examined.

On the sound shore, from Hempstead harbor eastward, most of the towns on the numerous small bays were visited; and it was the almost universal testimony, that, while Venus had formerly been taken in great numbers, the last two or three years had shown a surprising diminution in the number.

It will be seen, by comparing this with the report on Mya, that the results are practically identical. In Peconic bay and contiguous waters, and apparently in Jamaica bay, both clams are still taken in numbers. Almost everywhere else, both have practically failed, or are failing with great rapidity.

While we have described at some length the habits of Mya, and outlined a plan for its artificial culture, the life history of Venus is almost entirely unknown. There is evidently great need for such knowledge at present.

PECTEN IRRADIANS

Scallop

This peculiar form does not have so wide a distribution as either Venus or Mya. After attaining a certain size, Mya digs deep into the ground, and never removes itself from its burrow. Venus also covers its body in the sand or mud, though not deeply, and is able to creep on the bottom. But Pecten is a form which is able to swim by an opening and closing movement of the shell. This method of locomotion is not a skilful one, but is effectual, for the creature is able, in time, to compass considerable distances in its migrations. Pecten is a form which comes and goes, but it seems to choose definite localities for its resting places. These are usually small and more or less sheltered bays, where the creatures lie on the bottom, sometimes crowded together in great numbers, at other times much scattered. They may stay in one region for many months, and are taken from September till late in the winter.

The greater number of these forms are dredged along the shores of Peconic and Gardiners bays. A few are still taken in the bays on the sound. From the vicinity of Riverhead, nearly to Montauk, immense numbers of scallops are taken every year. There are probably few regions on the coast which compare with this in the richness of its supply of food mollusks. On account of the peculiar habits of the scallop, the catch in any single locality is always somewhat uncertain. Near Napeague harbor, for instance, for several years past the supply has been short, but during September of the present year (1900), dredgers who had been at work for several days reported unusually large catches. Marketmen seem to believe that the supply of scallops here is not diminishing. It was ascertained, however, that at many points more men than formerly had become engaged in the business of dredging. While the number of scallops sent to market may not be less, the beds are taxed more severely. Many of the older dredgers profess to believe that excessive dredging is already making a great difference in the average number of scallops taken each year.

To very many the scallop is the most highly prized of all mollusks, and it is to be hoped that it will long be spared. It must

be remembered, however, that it has been completely exterminated on some parts of the New England coast, and that, while the soft clam can undoubtedly be made again to flourish on depleted flats, it is to be doubted seriously if this can be accomplished with the scallop. The time to conserve the supply is while we still possess it.

Very little can be said of the life history of *Pecten*. Beyond the fact that it migrates and breeds during the summer (the limits of the breeding season have not definitely been determined), little is known of its life and habits. We do possess one other fact of interest concerning it, and that is that, when very young, it, like *Mya*, develops a byssus. In this case the structure is relatively large, and is made of many threads, by means of which the animal attaches itself firmly to foreign bodies. This byssus is retained till the shell is nearly or quite half an inch in diameter.

Many difficulties probably would be encountered in an attempt to rear *Pecten* by artificial means, the most serious of which might be in the habit of migrating from shallow to deeper water at certain times, though what the significance of these migrations may be is problematic. It is one of the most highly specialized and delicate forms in the group of mollusks, and the conditions necessary for its existence may be very exact, and hence difficult to discover. The fact that the young attaches itself to foreign bodies might be taken advantage of in the collection of large numbers, but it would not be easy, probably, to keep them till they had reached maturity, or to confine large numbers indefinitely on a restricted portion of the bottom. The only safe method now is to watch the supply as closely as possible, and to prevent its diminution by excessive dredging.

RELATIONS TO THE OYSTER INDUSTRY

In order to understand the clam problem in Long Island, it is necessary to refer to an apparent clash in the interests of oystermen and clam-diggers. It is claimed by the latter that the rapid extension of oyster beds in Great South and Peconic bays, as well as in other waters, is rapidly narrowing the area available for taking the hard clam. There is no question about the rapid spread of the

oyster industry, and it is a thing greatly to be desired. Unlike the depredations from which Chesapeake bay has always suffered, there is nothing piratical about the operations of the Long Island oysterman. He is a planter—not a mere dredger—and receives a title or a lease from the various towns for the territory which he occupies, and he is legally entitled to their protection.

It is to be hoped that this appropriation of the bottom is not to interfere seriously with the supply of clams and scallops. It seems that just now there is great need for the development of some method of hard clam culture. Oyster culture is well developed, and we know the conditions and the size of the area necessary for the production of a certain number. On the other hand, we know nothing of the possibilities of rearing the hard clam, and it may be that bottoms now not utilized may be made to produce—and perhaps in greater abundance than the natural beds.

It would probably be declared by oystermen that the spreading of oysters on a bottom does not destroy the clams which already exist there, and that, when the oysters are removed, the clams may then be taken also. It certainly would be an interesting thing to determine whether the presence of oysters on a clam bed would interfere greatly with the growth of the clams, or vice versa. This is simply a question of the necessary amount of food, for both certainly live on the same microscopic plants, which are borne by water currents. We should expect, then, to find the results of such an inquiry varying somewhat in different localities. If there should be areas, however, where food is so abundant as to allow the maximum rate of growth of both forms, it should be known, and the advantage of a double crop on one area realized so far as possible.

Surely this question of the relation between the oyster and clam industries is worthy of most careful consideration by the state of New York. Before it can be discussed intelligently, there must be a very careful investigation of the facts concerning the possibilities of growth of both forms. The life history of the oyster is fairly well known; but of the hard clam, almost nothing. We must become acquainted with the possibilities of the bottoms, considering not only the relations between oyster and hard clam, but also between

oyster and scallop. Without prejudice we must decide what would be the greatest good to the greatest number.

We need not here enter into a discussion of the ethical aspect of the case. One naturally has great sympathy for the weak, who are contending for existence against the strong. This is a practical question, and will be determined according to the desires of the majority of those interested. If we can not have them both in abundance, shall we have a sufficient supply of oysters or of clams and scallops? The answer to this question will determine the action. It is unfortunate in this case that we do not know more about the little-neck clam and the possibilities of its artificial propagation. For, under control, it is possible that the shores of Long Island are really sufficient to support both oysters and clams in such numbers as to supply the rapidly growing demand for both for some time to come. Venus can probably be cultivated as well as the oyster. The trouble lies in the difficulty of educating the public to an appreciation of the results already demonstrated in closely allied forms.

So far as the soft clam is concerned, the way is clear. When the general public has the facts which demonstrate the practicability of culture methods in this form, suitable legislation may be obtained for the protection of the new industry, which would surely arise. Not only is it absolutely essential that ancient laws governing the shore rights be repealed, but new and more favorable laws must be *enforced.*

When anyone is free to dig the beaches, it is folly to attempt culture methods. Suppose that laws are formulated, as they were in Massachusetts, which provide for the leasing of ground to individuals. Unless these laws are enforced by *state* authority, they are absolutely useless, as they were at Essex.

New York was far-sighted in providing for the oyster industry. Everyone rejoices in its great growth. Let us hope that, after a careful and unprejudiced examination of the possibilities of the new industries, and their relation to oyster culture, the state may also wisely provide for the development of clam and scallop culture.

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LIME AND CEMENT INDUSTRIES OF NEW YORK

BY

HEINRICH RIES Ph.D.

CHAPTERS ON THE

CEMENT INDUSTRY IN NEW YORK

BY

EDWIN C. ECKEL C.E.

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1901

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CONTENTS

PREFACE

The following report on the limestones of New York state deals with their uses in the various industries, but does not include the use of limestone for building or road construction.

It is hoped that it may serve two purposes:

1 To give information to quarry owners concerning the uses of limestone and the characters which the stone should possess, to make it of value for these different applications.

2 To supply limestone consumers with information regarding the extent and character of the limestone formations of New York.

Many quarries have been visited, and samples collected for analysis; and, while the chemical work has not been carried out in as much detail as might have been desired, still it is hoped that the analyses given may serve to prevent useless search in unpromising localities. In the preparation of that portion of the report relating to the testing and manufacture of cement the writer has drawn freely on many of the works referred to in the body of the report.

The writer wishes to express his thanks to the many quarry owners who have extended courtesies to him during the course of the work, and also to Dr F. J. H. Merrill, state geologist, for many valuable suggestions.

HEINRICH RIES

Ithaca N. Y. December 1900

LIME AND CEMENT INDUSTRIES OF NEW YORK

ORIGIN OF LIMESTONE

Limestones may be of either organic or chemical origin, those originating in the former manner including the more extensive known deposits, while the more local ones are confined chiefly to the second class.

Most surface waters contain carbonic acid and some organic acids in solution, and these, in percolating through rocks containing carbonate of lime, take the latter into solution in the form of an unstable bicarbonate. On coming in contact with the air, the latter is deposited either as stalactitic growths in caves, or on the surface around the spring formed by the issuing water. Such a deposit is known as travertin, tufa or calcareous sinter. In the United States extensive deposits of this type are unknown, but many local ones occur. The mammoth hot spring terraces in the Yellowstone park are examples of this, and in New York state deposits are found at many points, the best known perhaps being the so-called "petrified marl" at Mumford, and the tufa deposits near Clinton (N. Y.) In parts of Europe, specially Italy, large deposits of tufa are also known to occur. These deposits are all of fresh-water origin.

It seems probable that the deposition of the carbonate of lime may be due at times to the action of the atmosphere; still in some instances the lower forms of plant life undoubtedly play a part. C. A. Davis has recently shown[1] that in many Michigan lakes the deposition of marl is still going on, and points out that the precipitation takes place on the surface of certain small plants belonging to the C h a r a c e a e.

The precipitation may be caused in two ways. 1) If the water contains lime salts in excess, held in solution by carbon dioxid, the former will be precipitated when the latter is taken up by

[1] Jour. geol. 8: 485.

the plants. 2) If only a small percentage of lime is present, and in the form of bicarbonate, the latter may be converted into the simple carbonate by the action of the oxygen set free by the plants.

The greater number of limestone deposits are probably of organic origin, that is they result from the accumulation on the ocean bottom of the calcareous remains of marine organisms, such as the shells of mollusks, cases of foraminifera and skeletons of corals, etc.

Some writers have put forth the theory that many limestones, specially those showing no trace of organic remains, have been formed by chemical precipitation; this, it is argued, has been caused by reaction of alkaline carbonates on lime salts, or by the breaking up of bicarbonate of lime on exposure to the air, this salt having been often brought to the sea in river water. Dr T. Sterry Hunt was an earnest advocate of the precipitation theory.[1]

G. Bischof was an active opponent of this theory, arguing[2] that lime carbonate would not be precipitated under the conditions existing in sea water. To cause its precipitation in a manner similar to gypsum, Bischof reasons that 75% of the ocean water would have to be evaporated, in order to produce sufficient concentration.

The presence of crystalline grains of carbonate of lime intermingled with the shell fragments suggests the possibility of two causes, viz, organic and chemical, acting at the same time in the building up of the calcareous deposits. This may, however, be explained by the fact that calcium carbonate crystallizes very readily, even at ordinary temperatures, and that portions of the shell remains in the limestone may have been dissolved and reprecipitated.

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[1] Chem. and geol. essays. Ed. 4. 1891. p. 82, 311. *See also*, Lapparent, Albert de. Traité de géologie, p. 685; *also* Zirkel. Lehrbuch der petrographie, 3: 482.

[2] Chem. and phys. geol. 1: 581.

G. P. Merrill[1] states that "it is very probable that few of our limestones are wholly from organic remains, but are in part at least chemical deposits. The alternation of the beds of snow white, blue gray, greenish and almost black layers, as in the Vermont quarries, may be best explained perhaps on the assumption that the white layers resulted as deposits from solution, while the darker layers are but beds of indurated shell mud and sand colored by the organic impurities they contained at the time they were first laid down."

Fossils are sometimes plainly apparent in the limestone, but very often the shells become comminuted before settling on the ocean bottom, or they may be broken by the pressure of other material deposited on them, so that not infrequently limestones show no trace whatever of organic remains. Limestones of great purity have generally been deposited in the deeper parts of the ocean, or at least far enough away from the shore to prevent their contamination by silicious or argillaceous sediments brought down to the sea by rivers. The varying intermixture of such classes of material with the calcareous mud results in the formation of all grades of rock between a limestone and sandstone on one hand, and a shale on the other. A silicious limestone is one with silicious impurity, while a mixture in which the silica predominates is called a calcareous sandstone. In the same way, we may have a shaly or argillaceous limestone or a calcareous shale.

The consolidation of the limestone particles may be due to the precipitation around them of lime carbonate from the sea water, or it may be due to the percolation of carbonated meteoric waters through a mass of calcareous sand.

CHEMICAL COMPOSITION

Pure limestone is composed of carbonate of lime or the mineral calcite and consists of 56% of oxid of lime and 44% of carbon

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[1] Stones for building and decoration. 1891. p. 79.

dioxid. It rarely occurs perfectly pure, the impurities seldom falling below 1%, while they may increase to such an extent as to prohibit calling the rock a limestone. The impurities commonly present are silica, alumina, iron, magnesia and organic matter. Traces of sulfuric acid are also met with.

The silica may be present either as pure quartz; combined with alumina in the form of clay; or less frequently as an element of silicate minerals such as mica, hornblende or pyroxene. Silica may practically be looked on as an inert impurity displacing so much carbonate of lime. At high temperatures, however, when the carbonic acid has been driven off and oxid of lime left, the silica will flux the lime with great eagerness. Alumina is usually present as clay. With an increase in the percentage of the latter, limestone passes into cement rock. If present to the extent of only 4% or 5%, alumina is an inert impurity like silica, but, when present in larger amounts as a constituent of clay, it facilitates the expulsion of the carbonic acid gas. The reason for this is that clay contains chemically combined water, which passes off only at a red heat or at the same time as the carbonic acid gas. This provides an atmosphere of watery vapor into which the carbon dioxid escapes quicker than it would if passing off into gas of its own kind.

Iron and alkalis, if present in appreciable quantity, render the limestone more easily fusible, and may necessitate the hand-picking of the burned rock to separate clinkers. Limestones often contain appreciable amounts of magnesia. When the amount of MgO is 5% or higher, they are called magnesian limestones, but, when it reaches 18% or 20%, the term dolomite is more frequently employed. Organic matter is rarely absent from limestones, and a very small amount may impart a gray or even black color to the rock. While a total of 4% or 5% of impurities does not mean much when only a few tons of stone a day are used, it becomes an appreciable item when the consumption at one works amounts to 200 or 350 tons of limestone a day.

Limestones may be divided into lime rock and cement rock. The former when burned slakes, or falls to pieces in water with the evolution of heat. The latter when burned does not slake but forms a hard mass on the addition of water. The two kinds grade into each other, and under each group several subdivisions can be made, as below.

Limestones	Lime rocks	Limestone
		Magnesian limestone
	Cement rocks	Slightly argillaceous limestone
		Argillaceous limestone
		Argillaceous magnesian limestone

This classification is based on the composition and uses of the rock.

Whether dolomites have been derived by direct chemical precipitation or by secondary changes has been much discussed, some arguing for the former method of origin; but many for the latter, admitting the first explanation to hold good in only a few cases.[1]

It is definitely known, however, that dolomite is at times formed by the replacement of some of the lime carbonate of a pure limestone by magnesium carbonate. This process of dolomitization is accompanied by a shrinkage in the rock.[2]

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1 Geikie, A. Textbook of geology. Ed. 3. p. 321.

2 Zirkel, F. Lehrbuch der petrographie, 3: 509. Orton, E. 8th an. rep't U. S. geol. sur. pt 2, p. 641.

Table showing variation in composition[1] of limestones

	SiO_2	Al_2O_3	FeO Fe_2O_3	CaO	MgO	CO_2	H_2O	Insol.	$CaCO_3$	$MgCO_3$
Living organisms										
1 Coral	....	....	....	54 57	....	....	2.54	....	97.46	....
2 Reef rock	....	....	....	53.82	1.01	....	....	....	96 11	2.13
3 Lagoon sediment	....	....	....	54.58	.85	....	....	....	97.47	1.79
4 Coral	....	....	....	44.96	3.87	....	....	....	80.29	8.14
5 Oyster shells	....	....	....	44.1	1.3	35.4	14.5	....	79.28	2.73
6 Calcite	....	....	....	56	....	44	....	....	100	....
7 Dolomite	....	....	....	30.43	21.72	....	....	....	54.35	45.65
Marine limestones										
8	.63	.55		55.6	.23	....	....	....	99.3	.49
9	....	1.06		53.78	.34	....	.9	1.13	96.04	.72
10	....	....	1.25	53.89	.1	....	....	....	96.24	.21
11	1.84	.64	1.82	51.4	2.23	41.19	.27	....	91.8	4.68
12	12.34	7		44.41	44	....	....	....	79.3	92
13	3.77	.08	6.8	33.79	15 32	42.21	....	....	60.35	32.61
14	....	.55		29.54	21 08	....	1.82	.6	52.75	44.28
Waterlime										
15	18.34	7.49		37.6	1.48	....	3.94	....	67 14	2.9
16	15.37	11.38		25.7	12.44	....	1.2	....	45.91	26.14
Silicious										
17	....	1.2		17.69	10 59	....	1.24	43.72	31.6	22.24
Fresh-water limestone										
18	....	.37		54.16	.15	43.68	....	1.49	96.71	.31
19	....	1.83	.22	34.2	.11	26.79	4 64	31.23	61.07	.23
Travertin										
20	.08	.15		53.83	.9	41.79	1.43	....	94.97	.43

1 Kemp. Handbook of rocks, p. 70.

SOURCES

1 Sharples, S. P. Staghorn coral. (*see* Am. jour. sci. Mar. 1871. p. 168)
2 Hogbom, A. G. Bermuda coral reef rock. (*see* Neues jahrb. 1894. 1: 269)
3 —— Bermuda coarse lagoon sediment. "
4 —— Average of 14 analyses of the coral Lithothamnium. (*see* Neues jahrb. 1894. 1: 172)
5 Oyster shells. (*see* Geol. of New Jersey 1868. p. 405)
6 Calculated from $CaCO_3$
7 Calculated from $CaCO_3$, $MgCO_3$
8 Olcott, E. E. Crystalline Siluro-Cambrian limestone, Adams, Mass. For marble
9 Limestone, Bedford Ind. (*see* Min. ind. 3: 505)
10 Solenhofen lithographic limestone. (*see* G. P. Merrill. Stones for building and decoration, p. 415)
11 Egleston, Thomas. Limestone, Hudson N. Y.
12 Trenton limestone, Point Pleasant, O. *Vide no.* 10
13 Surface rock, Bonne Terre Mo.
14 Limestone, Chicago. (*see* Min. ind. 4: 508)
15 Hydraulic limestone, Coplay Pa.
16 Hydraulic limestone, Rosendale N. Y. (*see* Min. ind. 2: 49)
17 Silicious limestones, Chicago Ill. *Vide no.* 14
18 Woodward, R. W. Miocene limestone, Chalk Bluffs Wy. (*see* 40th par. sur. 1: 542)
19 Brewster, B. E. Eocene limestone, Henry's Forks Wy. (*see* 40th par. sur. 1: 542)
20 Whitfield, J. E. Travertin below hotel terrace Yellowstone park. (*see* 9th an. rep't director U. S. geol. sur. p. 646)

GEOLOGIC OCCURRENCE

Beds of limestone occur in deposits of almost every geologic age from Archaean to Tertiary. In New York state they are found in every formation except the Carboniferous, Triassic and Cretaceous.

Geologic age can not be looked on as an indication of purity or extent.

In New York the purest limestones come chiefly from the Trenton, though some are found in the Cambrian. Those of the Helderberg rocks seldom average over 92% lime carbonate. The

Guelph division of the Niagara, and the Cambro-Silurian (of Westchester county) yield the best dolomites.

PROSPECTING

The points to be considered in prospecting are topography, vegetation and appearance of outcrops.

Limestones as a rule weather quite readily, but the presence of impurities may exert an important influence in this respect. Pure limestone is easily soluble in carbonated water, consequently, when a bed of soft, pure limestone is inclosed between two harder rocks, dipping at high angle, the limestone may be dissolved away, leaving a valley between the more resistant layers. This fact is often noticed in Westchester county, where the section involves a basal gneiss, a limestone, and an overlying mica schist; the beds have been much folded, and the dip is often steep. Most of the valleys in this county exhibit gneiss on one side and mica schist on the other, while the intermediate limestone has been cut down by weathering to form a valley. (Pl. 2)

Many limestones contain sandy layers or chert nodules, or in some cases silicified fossils. In such instances the weathering of the rock is extremely irregular, the lime carbonate being dissolved out, while the silicified portions stand out in bold relief on the weathered surface. Limestones of great purity, however, may at times weather unevenly, solution for some reason not well understood, taking place along certain lines, thus producing a series of reticulated gashes extending inward from the surface of the rock.

In magnesian limestones the carbonate of lime is dissolved out, while the carbonate of magnesia yields but slowly to solution, the result being that the rock breaks down into a series of sand-like grains. The Guelph limestone of western New York shows this. Many dolomites, however, owing to the coarsely crystalline structure and insolubility, disintegrate rather than decompose,

Plate 2

To face p. 648

H. Ries, photo.

View of Inwood, Manhattan Island. Plain of Calciferous Trenton-limestone. Hills right and left of Hudson river schist. Palisades (Triassic) in the background

and in Westchester and Dutchess counties the outcrops of the crystalline dolomites are often found surrounded by an accumulation of white sand.

The position of the beds is a feature of considerable economic importance, specially when those in a quarry are of different quality. In the case of a steep dip the advantages are the possible extraction of the required layers without the necessity of disturbing the others, while the disadvantages are increased cost of hauling the rock to the surface, the deeper down we go, unless the entrance to the quarry happens to be at a lower level than that from which most of the stone is taken; with steeply dipping layers the rock may be weathered to a much greater depth than in the case of horizontal ones, because the upturned edges furnish a ready means of entrance to the weathering agents. In the extraction of individual layers the inclosing ones must be supported either by timbering or else by leaving pillars of rock; and, as quarries operated in rocks with a steep dip are often apt to go to much greater depth below the surface than other quarries, there may be an increased cost for timbering.

In the case of horizontal layers we have the advantages of having the haulage of the rock nearly all at the same level; the quarry will often drain itself; there is much greater space to work in and consequently the depth of the quarry can be much greater; the rock as quarried can often be loaded directly on the cars, the tracks being run into the quarry. The disadvantages of this method are that, if only certain layers are required or can be used, the upper ones have to be first removed in order to reach the desired beds of stone so that there is often much stripping.

This variation in dip must be carefully watched in some regions where the rocks have undergone considerable folding, as in the Hudson valley from Catskill to Kingston. Here at times the beds are nearly vertical, while again, only a few hundred feet farther, they may be nearly horizontal. Jointing has both its advantages and disadvantages. While the presence of joints

facilitates the extraction of the stone, yet they also serve as a ready means of entrance for the weathering agents.

Where the topography of the country is such that outcrops are scarce, the character of the vegetation may often serve as a clue to the character of the underlying rock. In New York the surface is usually covered by glacial drift and hence the bed rock exerts no influence on the tree growth, as it does in the southern states where residual soils are common. Streams which disappear in caves, and calcareous springs may also be looked on as evidencing the presence of lime rock.

In searching for calcareous beds, if the rocks are steeply tilted, it is better to follow a line at right angles to the strike, thus passing over the edges of the different upturned beds. In regions of little or no dip this plan is valueless, and a careful inspection must be made of ravines, valleys, and railroad cuttings. If the beds dip, the apparent thickness of the rock bed at the surface, measured at right angles to the strike, will be much greater than its real thickness, the difference being greater the less the dip. A rapid means of determining the real thickness of beds whose dip is under 45° is by the following rule: multiply $\frac{1}{12}$ of the apparent thickness by $\frac{1}{5}$ of the degree of dip. Thus, if the apparent thickness were 100 feet, and the dip 15°, the actual thickness would be $100 \div 12 = 8\frac{1}{3}$. $8\frac{1}{3} \times 3 = 25$ feet.

COLOR OF LIMESTONES

An absolutely pure limestone would be white, that being the natural color of calcite, but most limestones are colored either by iron oxid or organic matter. The former gives yellow, brown, red or gray colors, depending on the form of combination and stage of oxidation; while organic matter colors the limestone gray to black. A very small percentage of organic matter may color a limestone black, the black limestone of Fairhaven containing, for instance, less than 1% of impurities.

MINERALOGIC COMPOSITION

Pure limestone contains only carbonate of lime, and dolomite, if pure, would contain only carbonate of lime and magnesia. Impure limestones may contain many different mineral species. The commonest of these is quartz, which may be present either in the form of tiny grains or else as nodular masses (chert), popularly known as flint. Clay is also a frequent impurity, and iron oxid is common in some as a cementing material.

The greatest variety of minerals is usually found in those limestones which have been subjected to contact or regional metamorphism, as this causes a segregation and rearrangement of the original impurities of the rock, yielding new mineral compounds. Among the commoner minerals thus formed are pyroxene, amphibole, garnet, vesuvianite, epidote, zircon, wernerite, wollastonite, graphite, etc.

The many crystals of white pyroxene in the Westchester county dolomites, and the bunches of dark minerals in the limestones of the Adirondack region, and in those around Mt Adam, in Orange county, are examples of this.

In weathering the more silicious layers, or spots in the limestone, stand out in relief on the weathered surface, so that this often serves as a clue to the amount of mineral impurities which the rock contains.

Texture

Limestones, unless metamorphosed, are commonly fine grained, and may vary from fine earthy rocks to granular ones. Metamorphic limestones are often coarsely crystalline.

The hardness of the rock (not of the individual grains) will depend partly on the cementing material which binds the grains together and partly on the shape of the grains themselves, whether rounded or angular. The latter will have a tendency to inter-

lock. The relative hardness of a limestone may affect its commercial value in several ways. If too hard, the cost of quarrying it becomes great, and it will be more difficult to burn, whereas, if soft, it may tend to break up or pulverize in burning and consequently clog up the kiln. If we must use a silicious limestone, it is best to have one in which the silica is evenly distributed.

USES OF LIMESTONE

Limestone is used in the industrial arts to a large extent in either its raw or burned condition, and in the following pages an attempt has been made to describe 1) the uses of common and magnesian limestone 2) the uses of lime, and 3) argillaceous limestones or cement rock.

Paper-making

Much paper is now made from wood pulp, that known as sulfite pulp being a superior grade, in whose production considerable quantities of both dolomite and limestone are used. The following description of its use has been kindly furnished to me by T. A. Howard, of the Vermont marble co.

The broken stone is thrown into cylinders, 8 feet in diameter and 20 to 160 feet high. When the tubes are full, fumes of sulfuric acid are led into the bottom, and water allowed to trickle down from the top. The stone thus becomes slowly dissolved, and the liquor is drawn off into storage tanks. This solution is used to "cook" the wood. The latter is cut into chips one or two inches long, and put in a "digester" holding seven or eight cords of wood. The liquor is also introduced, and the mixture heated by steam is under pressure for several hours. The sulfite of lime or magnesia removes all the pitch and everything except woody fibers, and at the same time removes all discoloration.

Some manufacturers say that the liquor can be made faster and stronger by the use of dolomite, in order to get which they

sometimes go 10 or 12 miles from a railroad. When limestone is used, the cylinders generally seem to be made higher. In New York state dolomites are available in Westchester, Dutchess, Monroe and St Lawrence counties specially.

Glass-manufacture

The lime contained in glass is commonly added to the mixture in the form of crushed limestone, this being preferable to the burned rock, which may change in composition by the absorption of water or carbon dioxid from the air. Limestones containing iron oxid or magnesium carbonate should be avoided, since the former colors the glass and the latter makes it less fusible. Dolomitic limestones are used, however, in glass-making.

Next to silica lime is the most important of glass-making materials, as it renders the soda and potash of the glass less soluble and promotes the fusion of the materials, thus improving the quality.

Glass rich in lime requires a higher temperature to melt and, because of this, is more destructive to the pots, but, used in proper proportions, lime promotes the fusion, aids in the decomposition of the materials and improves the quality of the glass. Lime glass can not compete with lead glass in brilliancy, but it is harder, not so easily scratched, holds its polish longer, is more elastic and consequently tougher, will stand higher temperature, resists better the action of water and chemical agents, and is much more cheaply produced. On account of the slight difference in specific gravity of the two substances composing it, lime glass is also less liable to striation. In the manufacture of plate glass, which is ground and polished, it is found that glass which is rich in lime is harder to polish than that poor in lime, but holds its polish better and longer, and also increases its resistance to weathering, as well as preventing it from "sweating", which happens in glass having an excess of alkalis. It may devitrify from the presence of excess of lime, as when an excess of lead

or sand is used. The lime should be as free from impurities as possible, specially oxid of iron.

Below are given two analyses, no. 1 from Blair county (Pa.) and no. 2 from Sandusky (O.) The former is used for window glass, the latter for lime flint glass.

Organic matter	.09	.05
Silica	1.01	1
Alumina	.02	.4
Ferric carbonate	.165	.....
Magnesium carbonate	1.48	41.43
Lime carbonate	97.23	55.6
Ferric oxid	.....	.12
Moisture	.....	.4

In the manufacture of tableware lime furnishes a cheap substitute for lead.

Furnace flux

This is one of the commonest uses of limestone. It is used as a flux for both lead and iron ores. In the blast furnace the action of the limestone is to reduce the iron to its metallic state and also flux the impurities, which pass off as slag. The purer the limestone the more efficient will be its action and the cheaper its use, for it will be easily seen that the greater the percentage of impurities the more limestone will be required to do the same amount of work. For reasons of economy blast furnace operators often use less pure but more easily and cheaply obtained limestones.

Some time ago a table was prepared by J. M. Hartmann,[1] giving the value of limestone containing varying amounts of silica, lime and magnesia. The basis of the calculation is magnesian limestone at 56c a ton and fuel at $3.50 a ton, both at the furnace.

1 Mineral resources of U. S. 1883–84, p. 670.

Values of various limestones

LIMESTONE			MAGNESIAN LIMESTONE											
Silica per cent	Lime per cent	Value cents	Silica per cent	Lime per cent	Magnesia per cent	Value cents	Silica per cent	Lime per cent	Magnesia per cent	Value cents	Silica per cent	Lime per cent	Magnesia per cent	Value cents
0	55	57	0	37	16	64	0	41	12	61	0	45	8	59
1	54	54	1	37	16	61	1	41	12	58	1	45	8	56
2	53	51	2	36	16	58	2	40	12	56	2	44	8	53
3	52	48	3	36	16	56	3	40	12	53	3	44	8	51
4	51	45	4	35	16	53	4	39	12	50	4	43	8	48
5	50	42	5	35	16	50	5	39	11	47	5	43	7	45
6	50	39	6	34	15	48	6	38	11	45	6	42	7	42
7	49	36	7	34	15	45	7	38	11	43	7	42	7	40
8	49	33	8	33	15	42	8	37	11	40	8	41	7	37
9	48	30	9	33	15	39	9	37	11	37	9	41	7	34
10	48	27	10	32	15	36	10	36	11	34	10	40	7	31
11	47	25	11	32	15	34	11	36	10	32	11	40	6	29
12	47	23	12	31	14	31	12	35	10	29	12	39	6	26
13	46	20	13	31	14	28	13	35	10	26	13	39	6	23
14	46	17	14	30	14	25	14	34	10	23	14	38	6	20
15	45	14	15	30	14	22	15	34	10	20	15	38	6	17

Limestone in excess purifies the iron from sulfur and also prevents the reduction of the silica to silicon.

Sugar manufacture

Much limestone is used in the manufacture of beet sugar, and here again the raw material must be of the proper composition. Both clay and sand are injurious impurities, as they increase the loss in lime in making the limewater, and the clay also introduces alkalis into the sugar juice. The sugar manufacturer considers that every part of insoluble matter means a loss of three to four parts of carbonate of lime. When, therefore, a limestone containing 95% carbonate of lime is paid for as if containing 100%, a stone with 85% should only be paid for as if containing 60% to 70%. If the lime is to be used for separation, the presence of much magnesia is injurious for the reason that it will not unite with the sugar as the lime does, forming a monosaccharate of lime which is essential before precipitation takes place. Consequently a large amount of magnesia hydrate in the lime necessitates the use of so much more of the latter and may also cause

loss in sugar. A limestone to be used in sugar manufacture must not have more than .25% alkalis.

The following are analyses of limes used by German beet sugar manufacturers.[1]

	CaO	Al_2O_3 Fe_2O_3	MgO	K_2O Na_2O	H_2S	SO_3
Limhamn, Sweden ...	95.6	1.62	.79	.03	....	....
Plymouth, Eng.......	95.22	2.44	....	...	....	....
Gogolin, Ger. (?)	89.82	7.28	1.04	.03	....	....
Gr. Kunzendorf, Ger.	96.66	1.1	.86	.05	....	....
Ober-Kauffung, Ger...	97.72	1.2	.7	.06	....	.15
Kösen, Ger.	97	1.52	.92	.01	....	....
Osterwiek..........	93.06	5.8	....	...	....	tr
Lauffen	90.12	7.6	2.19	.03	....	....
Atzendorf	89.04	8.8	1.24	.05	much	much
Borne	78.24	13	2.24	.06	....	....
Rüdersdorf..........	94.76	2	.74	.03	....	....

It will be noticed from the above analyses that in most of the samples the percentage of lime is over 90%, though in some it is under 80%. Another noticeable feature is the low percentage of both magnesia and alkalis, specially the latter. One shows the presence of much H_2S and another of appreciable amounts of SO_3.

It is the custom for beet sugar manufacturers to burn their lime themselves, for the reason that the carbon dioxid gas is also used in the process. For the production of the best results, it is therefore important that the limestone shall be of proper quality, and the burning conducted in the right manner.

Silica is a deleterious impurity, as it not only causes the stone to fuse but also lowers the amount of lime and carbon dioxid produced to each ton of stone used. This latter point is of course true with regard to any other impurities which may be present.

Too little fuel should also be avoided, as it decreases the amount of CO_2 produced. The stone used should be compact and hard. An excess of moisture, as 5% or over, should not be present, as it reduces the temperature of the kiln when first charged. Stones

[1] Thondindustrie zeitung. 1897. p. 1165.

containing an excess of moisture also tend to split in burning. About 1% of water is the proper amount. Magnesia is not specially objectionable except when silicates are present in the stone. It causes difficulties, however, in the purification of the sugar juice; consequently it should be at a minimum. Sulfate of lime may act the same as magnesia.

If silica is present, part of it passes into the juice with the lime and retards the filtration process by coating the cloths in the filter press. Silica also forms part of the scale on the heating surface. There is less harm from this source in hard than in soft stones. Silica and alumina also tend to form an insoluble coating on the burned lumps which interferes with the slaking.

The following analyses together with most of the above information on the stones used are from a report on the beet sugar industry of the United States dep't agric., 1897, p. 205.

	1	2	3	4	5	6	7	8	9	10
Moisture	4.1	5.1	7.25	4.15	4.17	6 25	5.16	.52	1.21	.11
Insoluble	4.5	5.15	4.9	2 15	3 07	3.17	2.25	2.85	.55	.27
Organic matter	1.2	1. 7	1.37	1.05	.97	1.12	.86	.3	.41	.15
Soluble silica	2.1	1.75	3.3	1.05	.98	.64	.56	.06	.2	.08
Iron and alumina oxid	.37	.41	.27	.17	.19	.15	.2	.32	.23	......
Lime carbonate	85.86	85.12	81.67	90.13	88.65	87.93	90.03	93.8	96.58	99.1
Magnesia carbonate	.95	.47	.59	.75	.95	.5	.45	1.81	.5	......
Alkalis	.05	06	. .	.1	.01	......	......	.. .	......	......
Undetermined	.87	.77	.65	.45	1	.24	.39	.34	.32	.34

Of the above nos. 1, 2, 3, and 4 are considered bad; 5, 6 and 7 are passable; 8, 9, 10 are excellent. No. 3 was used in a sugar factory and caused trouble, notably "scaffolding" or difficulty in the mechanical filters. No. 9 was substituted and these difficulties disappeared.

In looking over the analyses of limestones given in this report it will be observed that limestones of as great purity as nos. 8, 9, and 10 in the foregoing table are not uncommon in New York state. There are at present two beet sugar factories in New York state, the one at Binghamton and the other at Rome.

The following are some additional analyses of limestones used in beet sugar manufacture. Nos. 1 and 2 of stone used at Los Alamitos (Cal.), and no. 3, a French stone.

No. 1, the Colton stone, is good. No. 2, Oro Grande, is passable. No. 3 is bad.

	1	2	3
Lime carbonate	98	94.306	81.67
Magnesium carbonate	.453	1.845	2.5
Iron and alumina oxid	1.096	.929	.27
Silica, sand, etc	.281	.9	8.2
Moisture	.051	.038	5.25
Organic matter and magnesium sulfate	......	.701	1.37
Undetermined	.116	1.281	.64

Lime is used in the cane sugar industry chiefly to effect neutralization of the acidity in the juices. "Lime is soluble in about 780 parts of water at 15° C and in 1500 parts at 100° C. Alcohol dissolves only a trace. Sugar water dissolves it in large quantity, whereby the lime enters into chemical combination with the sugar, forming sugar of lime. This fact is technically employed in separating sugar from molasses. The molasses is treated with lime, and the resulting sugar of lime is decomposed by the action of carbonic acid, forming calcium carbonate and pure sugar. Strontium has however lately displaced the lime in this process. 100 parts of cane sugar dissolved in water will dissolve 50–55 parts of lime."[1] I am informed by Dr F. G. Wiechmann that the lime used by the Brooklyn refineries is obtained from Glens Falls.

Chlorid of lime

Limestone which is to be used for this purpose must be very clean, for on this hangs the possibility of making strong and stable chlorid of lime. To satisfy these requirements the limestone must be sufficiently pure and thoroughly burned; consequently many manufacturers of lime chlorid purchase the limestone and burn it themselves. The burned lime should be free from carbonate of lime, and the limestone should have a minimum amount of sand, clay or similar impurities, which in burning do

[1] Frasch. Min. ind. 7: 495.

not turn into lime. Aluminous limestone clears with difficulty when dissolved, and hence is not liked by bleachers and paper manufacturers.

As the consumers require a pure white lime, the stone must contain practically no manganese or iron. These impurities are thought by some to also injure the stability of the lime chlorid, but this point is not definitely proved. The presence of magnesia is also undesirable, as the greater deliquescence of the magnesium chlorid renders the lime chlorid less stable. The presence of organic or bituminous substances in the limestone is entirely harmless, as they do little more than impart a dark color to the stone and pass off in burning.[1]

Fat limes which slake quickly and fall easily to a fine, light powder absorb chlorin much more quickly than lean limes, which on slaking give a sandy powder. In addition, chlorid of lime made from fat limes keeps much better than that made from lean limes.[2]

Carbon dioxid

A considerable amount of nearly pure dolomite has from time to time been shipped from the quarries at Pleasantville, Westchester co., for the manufacture of carbon dioxid. The stone was ground at the mines almost to the fineness of granulated sugar. From the grinder it passes into hoppers, whence it is fed automatically through tubes into barrels for shipment. The Quaternary marls near Caledonia have found favor for the same purpose, being utilized in Buffalo.

Soda manufacture

In soda-making by the Le Blanc process limestone is used to transform the sulfate of soda into caustic soda, the reaction being thus.

$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl$; $Na_2SO_4 + 2C = Na_2S + 2CO_2$; $Na_2S + CaCO_3 = Na_2CO_3 + CaS$.

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[1] Wagner. Chemische technische untersuchung's methoden. 1893. p. 430.
[2] Wright. C. R. A., Chem news, 16: 126.

Lithographing

Lithographic limestone is a somewhat impure, very fine and even grained limestone. It is not only rare but valuable. The requirements are sufficient porosity to absorb ink and softness enough to permit working with an engraver's tool. A very great degree of porosity is undesirable. The stone should also be free from cracks, or specks of impurities.

The chief supply thus far has come from Solenhofen, Bavaria and southern France. It has been reported from various localities in this country but never from New York state.

Lime

When limestone is burned, that is when it is raised to a red heat, it is dissociated into lime oxid and carbonic acid thus.

$CaCO_3$	=	CaO	+	CO_2
limestone or		lime oxid		carbonic acid gas
lime carbonate		quick lime		carbon dioxid
		caustic lime		

The carbonic acid gas passes off and the oxid of lime remains behind as a powdery or lumpy substance, which is often white, but may be more or less colored if iron is present.

As limestone varies in composition, the lime will also, but the percentage of impurities in the lime will be nearly twice what they were in the limestone, for the latter has lost 44% of carbonic acid gas.

Pure limestone consists of 56% of oxid of lime (CaO) and 44% of carbonic acid. The change from carbonate of lime to oxid of lime occurs during the burning, the carbonic acid being driven off at a higher temperature, and in this process the lime loses about 44% by weight; but, as it is generally in a somewhat moist condition when it is put into the kiln, due to water in its pores, the loss in weight may be still greater than that mentioned above. The percentage of moisture in limestone is very variable and depends largely on the hardness and density of the rock. The denser a limestone the less porous it will be and the lower will

be the percentage of quarry moisture in it; while the looser or more spongy it is, the more moisture will it absorb. Marl and chalk may be looked on as the loosest forms of limestone, and in them the moisture may reach 36% or 40%. In marls and bituminous limestones the loss in burning will of course be much greater than 44%, owing to the contained water and bitumen. A dense limestone is much harder to burn than an open-textured one, and requires more fuel, but this increased consumption is more than made up for by the quality of the lime obtained. In a clean, dense limestone the percentage of quicklime may be 54% while in an impure one it may amount to only 30% or 35%.

In addition to the decrease in weight in burning, the limestone also decreases somewhat in volume, as much as 12% to 21%, but usually 16% to 18%.[1]

In burning it is important to observe that the temperature remains as constant as possible and varies only between certain limits; for, when limestone is overburned, the lime made from it slakes slowly and incompletely. In lime rock with clayey impurities a sintering is very apt to occur and this should in all cases be strictly avoided; but it is true that the higher the temperature within the permissible limits the denser will be the lime. On the other hand, the temperature must not get too low, as in this case any large pieces of limestone that may be in the kiln will not become thoroughly burned. The unburned core resulting from underburning makes the lime lean, and, to avoid such an occurrence as far as possible, it is advisable not to put too large pieces into the kiln.

The quicker such lime is burnt at the highest temperature possible the more readily it slakes, and therefore a slow burning process is disadvantageous.

Many different types of lime rocks are available for the manufacture of lime, those only being excluded which are contaminated with clay; for this latter substance often affects their most important properties, and it is only since the beginning of this

[1] Schoch, C. Die moderne aufbereitung und wertung der mörtel-materialien, p. 57.

century that the special application of limestone with a large amount of clay has been recognized.

The lime made from pure or nearly pure limestone is sometimes called air lime in contradistinction to hydraulic lime made from aluminous or clayey limestones.

Burning lime.[1] "The time required depends on the density and size of the lumps of stone and also on the moisture content; for water aids to a certain extent in carrying off the carbon dioxid. It is stated that in the presence of steam limestone can be burned in one eighth the time required in dry air and the gases of combustion. This accounts for the fact that stone freshly quarried can be burned faster; it has not yet lost its quarry moisture. Periodical injections of steam or water into the kiln are recommended by some, but are not always necessary in the case of flame kilns."

Limestone which is burned too slowly will make lime of inferior quality and will slake more slowly.

Limestone begins to lose its carbonic acid gas at 750° F, but it does not entirely pass off till the temperature of 1300° or 1400° F is reached. Limestone should never be burned with a coal running high in sulfur, as the latter unites readily with the lime, forming calcium sulfate. This sulfate of lime reacts subsequently with the aid of moisture on any alkalis that may be present, with the formation of alkaline sulfates, which being soluble, are often brought to the surface after the lime is in the wall, forming thus the unsightly white coating that is sometimes seen on bricks. This coating may also be at times caused by the presence of soluble sulfates in the clay.

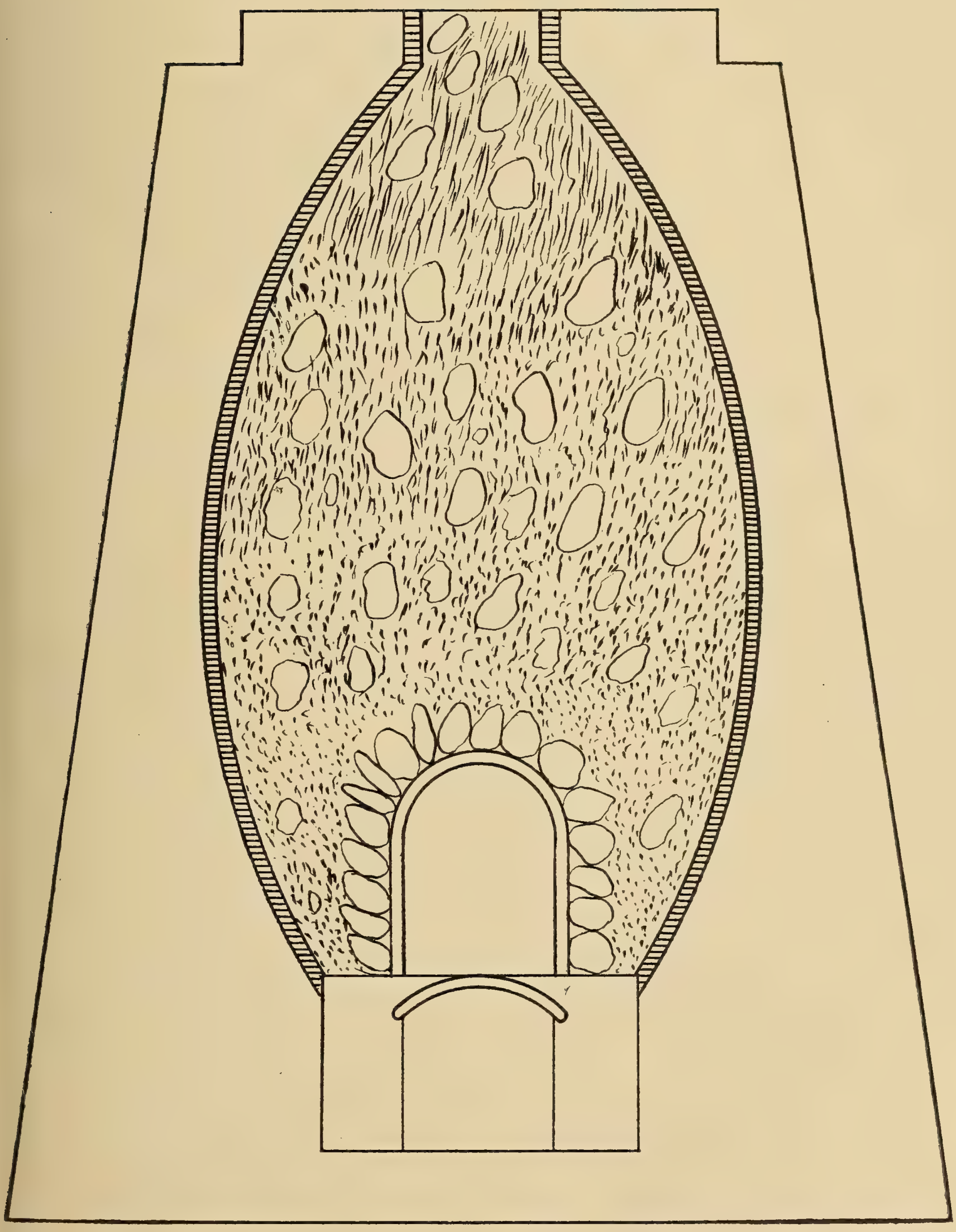
Limekilns. The kilns used for burning lime bear more or less similarity to each other, the general principle of construction being that of a cylindric chamber, lined with fire brick, open at the top and tapering below to a discharge opening.

Limekilns are either continuous or intermittent in their action.

In the latter the stone is put into the kiln with alternate layers of fuel till the kiln is full. The fire is lighted, and the mass

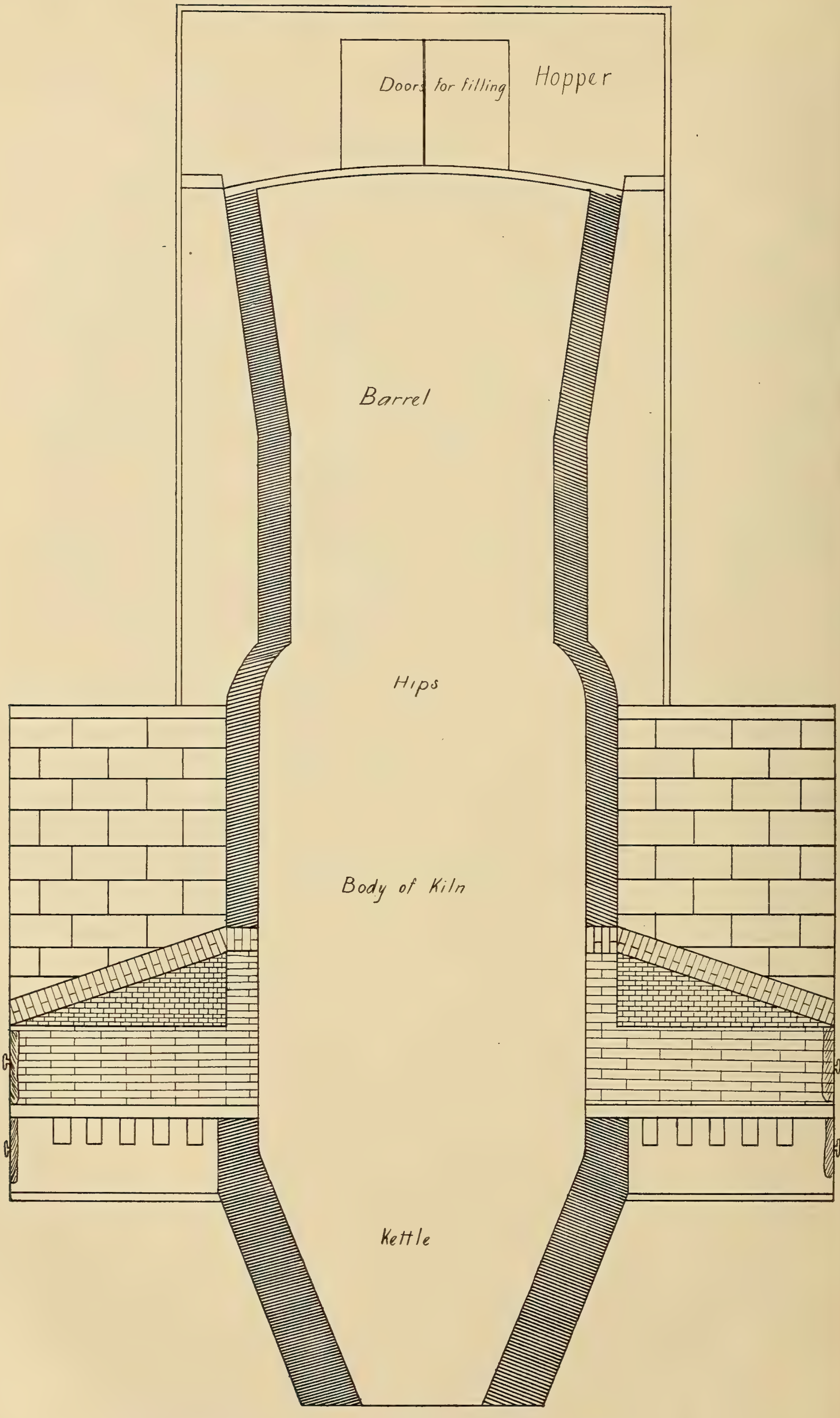
[1] Frasch. Min. ind. 7: 483.

Plate 3



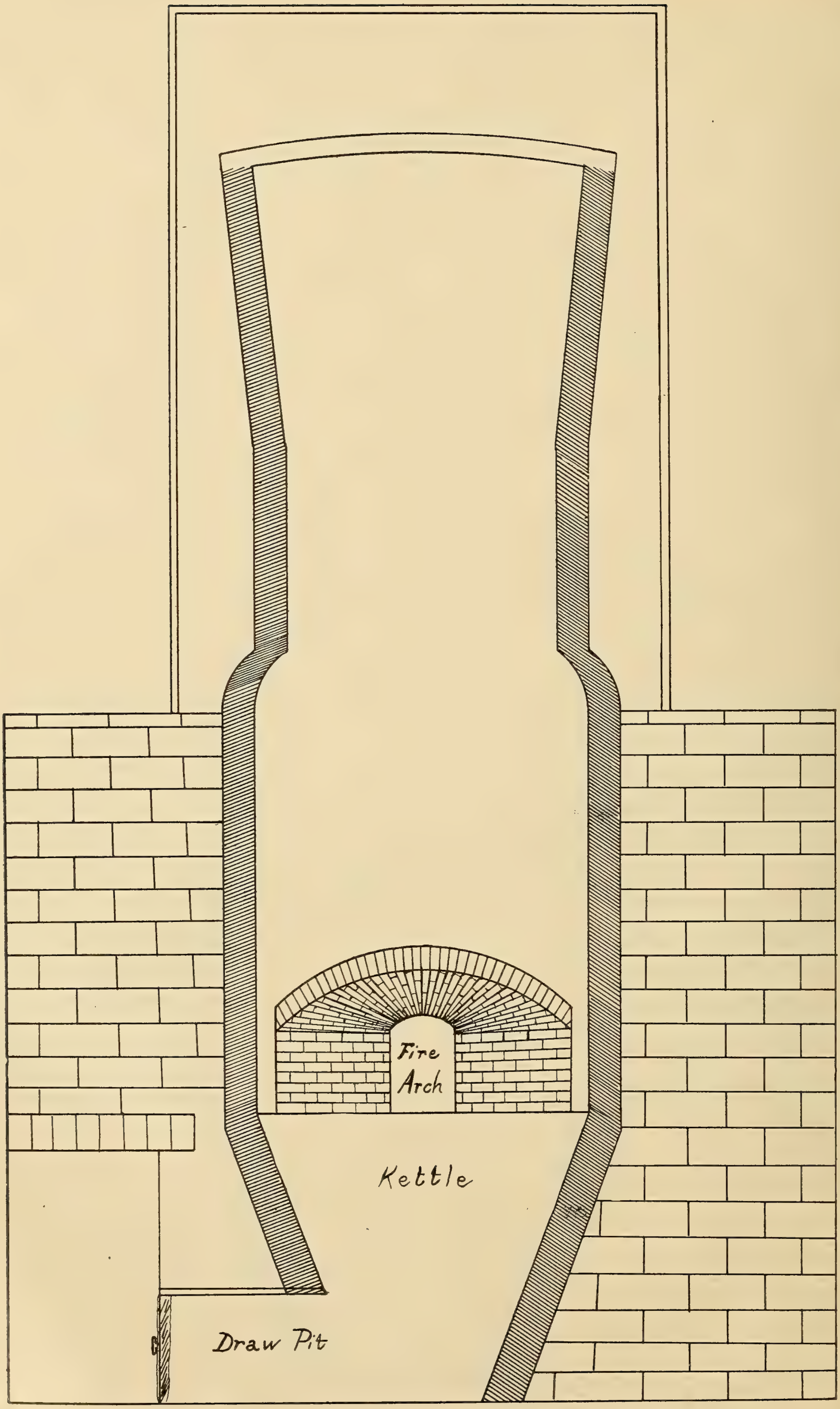
Section of lime kiln, after Gilmore

Plate 4



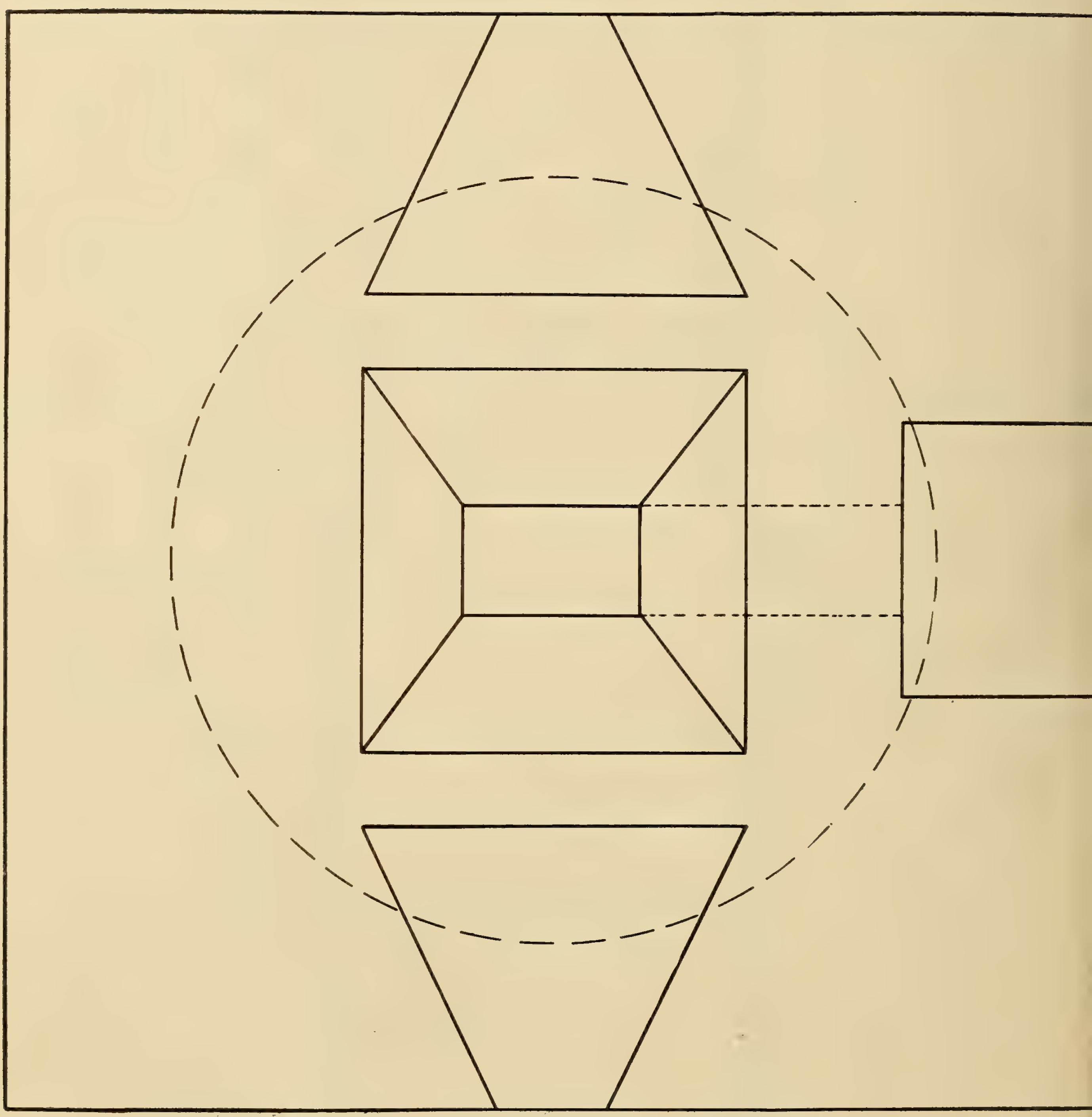
Vertical section of lime kiln, furnished by W. P. Nason, Glens Falls

Plate 5



Vertical section of lime kiln, furnished by W. P. Nason, Glens Falls

Plate 6



Plan of kettle of lime kiln, furnished by W. P. Nason, Glens Falls

allowed to burn itself out, after which the burned stone is drawn off at the bottom of the kiln. The principle of such a kiln is bad, because it necessitates a mixture of the stone and the fuel, whose ashes may dirty the lime (pl. 3).

In the continuous kilns, the fuel does not come in contact with the stone; for fireplaces are built in the sides of the kiln several feet above the bottom. These fireplaces are arched openings, which extend from the exterior to the interior of the kiln. Into these the fuel is put, and burned, thus permitting the flames to pass upward through the stone, but preventing the ash of the fuel from coming in contact with it.

The older forms of kilns were massive stone structures, with thick walls, and having the chamber lined with one or two layers of fire brick. The more modern ones are circular in form, with much thinner walls, and bound with sheet iron plates.

In the accompanying plates are shown several forms of lime-kilns (pl. 4, 5, 6).

The lime obtained by the burning of limestone is a white, amorphous, more or less dense mass, with a specific gravity of 3.09. It is infusible. Lime weighs from 1400 to 1800 pounds to the cubic meter, the variation in weight depending on the density of the original rock and the degree to which it has been burned. Denser stone gives a denser lime.

Impurities. "Limestone containing silica and alumina should not be burned at too high a temperature, because of the sintering that takes place on the outside of the lumps and thereby interferes with the escape of the carbonic acid, yielding dead burnt lime, which does not slake completely.

It is said that dead burnt lime is more apt to be formed if the impurities are evenly diffused in the stone. The ashes of the fuel and also the alkalis in the stone may cause dead burning.

The best limestone, if heated too quickly but not long enough, may give dead burnt lime, in which case a basic calcium carbonate is formed, which with water forms a mixture of calcium carbonate and calcium hydrate and hardens.[1]

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[1] Frasch. Min. ind. 7: 483.

More than 10% of magnesia makes the lime short, and 25% to 30%, it is asserted, renders the stone unfit for burning;" nevertheless, such stone is burned in the southeastern part of New York state.

10% of silica, it is maintained, gives the lime hydraulic properties.

Frasch also states that limestone of 95% purity yields 59% burnt lime with 90% calcium oxid; of 90% purity, gives 60% burnt lime with 80% CaO; 85% stone gives 65.5% with 72% CaO, and 80% stone gives 70% with 64% CaO.

Slaking. Lime in its normal condition and when dry is totally unaffected by carbonic acid gas but when heated takes it up rather quickly. The addition of water to lime can be done in a variety of ways according to the degree of slaking that is to be brought about. If a lump of quicklime is immersed in water for an instant it saturates itself at once, and this absorption is accompanied by the evolution of heat and a swelling and bursting of the lime, which finally falls to a fine powder, the hydrate of the lime, $Ca(OH)_2$. The chemical action which has taken place is expressed by the formula $CaO+H_2O=Ca(OH)_2$.

This method of hydration is considered to be better than pouring the water on the lime.

The hydrate of lime thus obtained is a fine, white powder of a specific gravity of 2.1. Its water of hydration is pretty firmly combined and is only driven off by reheating to redness.

Fat limes slake very fast and produce more heat than lean ones, and lime will slake even in the air by the absorption of moisture, so that, if not used immediately, it should be protected from the atmosphere as much as possible.

Lime may also be slaked by putting the lumps in water for a few minutes, then withdrawing and packing away to allow the lime to change to powder. The common method usually employed in building operations is to mix the lime with water in a box. Too much water makes it thin and injures its cohesive strength. If only a part of the water required is added at first

and the rest later, the lime becomes granular and lumpy. An excess of water in slaking is also undesirable, as it tends to lower the temperature of the mixture, and it is therefore well to use hot water if this can be done conveniently.

The hydration of lime powder or slaking to a pasty mass must be carried out very carefully, as otherwise, specially in the case of overburned lime, some unslaked particles will remain, which may slake later and make themselves unpleasantly prominent.

As water is added to the lime, it gradually forms a stiff paste, whose stiffness increases with the purity of the lime.

With careful slaking, 1 cubic meter of fat lime gives 2.7 cubic meters of paste and 1 cubic meter of lean lime gives 1.8 cubic meters.[1]

The excess of water is gotten rid of in part by evaporation and is also drawn off, while the slaked, pasty mass is allowed to stand in the pit to insure thorough slaking of every particle.

In the pits lime will hold itself for a long time without change provided it is properly protected from the air, but the damp lime paste absorbs carbonic acid greedily with the formation of carbonate of lime, which solidifies. The crust of calcium carbonate which forms is very thin, but it prevents the action from continuing farther in the mass. The solidifying action of the lime alone is of little importance and becomes of value only when sand is added. The use of the sand prevents large masses or lumps of the lime from collecting in any one spot and not becoming thoroughly converted into the carbonate.

Quicklime is a strong base and absorbs water with the greatest avidity, and in water it forms a milky liquid known as milk of lime.

On the other hand, quicklime can be made by adding the lumps of lime piece by piece to the water till a strong paste is formed by stirring the mass. The stirring is specially necessary in the case of lean limes.

In order to assist the slaking of such lean limes, it has been found advisable to use only one third the necessary amount of

[1] Schoch, C. **Die moderne aufbereitung und wertung der mörtel-materialien,** p. 59.

water at first and add the other two thirds later on. Again, as the lean lime gives out much less heat, it is well to keep the mixing pan covered in order to prevent its escaping. Lean lime also slakes better if a certain amount of fat lime is worked in with it. The latter has a sort of contact effect on the former, which is effective and rapid, so that this method is a good one to follow in using overburned lime.

Depending on the amount and nature of the impurities present, Gilmore divides natural and artificial limes suitable for mortar into five classes.[1]

"1 Common or fat limes
2 Poor or meager limes
3 Hydraulic limes
4 Hydraulic cements
5 Natural pozzuolanas

The common or fat limes contain less than 10% impurities, and a part of the latter are insoluble in water, all the rest of the lime being soluble. They do not harden under water but crumble or slake and increase in volume sometimes threefold. They shrink in hardening, and to prevent this sand must be added.

Poor or meager limes have from 10% to 25% of impurities, or sometimes even 39%.

Hydraulic limes are of three kinds:

a Slightly hydraulic ones with 10% to 20% of impurities
b Hydraulic limes with 17% to 24% impurities
c Eminently hydraulic limes with 20% to 35% of impurities[2]

All hydraulic limes harden under water. Hydraulic cement is an artificial product. It has less lime than the other classes, but not under 29%.

Natural pozzuolanas are rocks of igneous origin. They possess hydraulicity and generally under 10% of lime.

It is of course possible to find all intermediate grades between limes and cements.

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[1] Gilmore. Limes, hydraulic cements and mortars, p. 69.
[2] " " p. 71.

USES OF LIME

Basic steel

In the basic or Thomas and Gilchrist process the furnace or bessemer converter is lined with some basic material (that is material containing little or no silica), such as magnesite or dolomite. In this country the latter specially is used. Two things are required of the dolomite, viz, it should contain as high a percentage of magnesia as possible, and it should not have over 1½% or 2% of total fluxing impurities. It is specially important that the silica percentage shall be low, viz, under ½% if possible, for at high temperatures the lime or magnesia will eagerly unite with any silica present, and, as this action is equivalent to corrosion of the lining, any additional percentage of silica will materially affect the life of it. Pure dolomites are rare and when found are not always in easily accessible localities, but in this state two different bodies of nearly pure dolomite are known, the one at Ossining and Tuckahoe, Westchester co., the other at Rochester, Monroe co.

For use the dolomite is first burned to the sintering point and then ground and mixed with tar or other material to hold it together and permit molding.

The lime used in basic bessemer converters likewise has to be of great purity, and the stone must be of such a nature that it will burn to a lumpy and not a powdery lime; for, if the lime were added to the converter in the form of powder, the strong blast would quickly eject a large portion of it.

Refractory bricks

It is well known that oxid of lime is very refractory, a familiar illustration of this fact being the lime pencils used in the oxyhydrogen blow pipe. Consequently lime is often used for lining the bottom of the hearth in a reverberatory furnace used for the manufacture of basic steel by the Siemens-Martin process. The lime serves to extract the phosphorus from the iron, and a high

phosphorus slag is formed which is known as the Thomas phosphate.

Ammonium sulfate

In the manufacture of aqua ammoniae from ammonium sulfate lime is used to form sulfate of lime and thus liberate the ammonia, sufficient quantity being required to convert all the sulfuric acid in the sulfate and about one third more.

The lime is added in nearly every instance in the form of milk of lime, caustic of lime being employed in rare cases with a view to utilizing the heat evolved during the slaking, as in the Solvay process. This is not to be recommended, however, owing to the uncertainty which exists as to the time required by the lime to slake; for, if the latter is slow slaking, a temporary shortage of lime results, followed by a momentary excessive reaction, and, if any stoppage of the apparatus occurs, explosion may, and indeed at times does, result.[1]

The lime milk should be free from unslaked particles or sand grains, and magnesia is undesirable from the fact that it retards the distillation if ammonium chlorid or sulfate is present in the gas liquor, since it forms a double salt with them which can not be decomposed except at high concentration.

Contents of 1 liter of lime milk

Degrees Baumé	1 liter weighs grams	Lime grams	Water grams	Per cent lime
10	1 258.6	133.3	1 125.3	10.6
15	1 345	179.7	1 165.3	13.2
20	1 436	224.3	1 211.7	15.68
25	1 478	258.3	1 219.7	17.52
30	1 490	276.7	1 213.8	18.67
35	1 495.4	289.1	1 206.3	19.43
40	1 499	297.9	1 201.1	19.88
45	1 501.2	303.7	1 197.5	20.22
50	1 503.2	308.3	1 194.9	20.48
55	1 504.6	311.9	1 192.7	20.7
60	1 505.8	314.7	1 191.1	20.89
65	1 507	317.2	1 189.8	21.05

[1] Frasch. Min. ind. 7: 45.

Milk of lime

Frasch states that the slaking of lime is mostly done in wooden boxes. For industrial purposes, where the lime is used in the form of milk, as in the distillation of ammonia, mechanical devices are employed for this purpose. The amount of lime present in milk of lime of different density is given in the above table from page 496, vol. 7 of *Mineral industry*.

Soap

In the manufacture of soap slaked lime is mixed with carbonate of soda to produce caustic soda. The two are mixed with water, and boiled with steam, the resulting carbonate of lime being separated by settling.[1]

Lime is also used in the manufacture of soft soap, in that the pearlash of commerce is converted into caustic potash by means of fresh lime. In the manufacture of stearin for candles ordinary tallow is boiled in wooden vats by high pressure steam with slaked lime for several hours, by which lime soap is formed. This is transferred to another vessel and treated with dilute sulfuric acid, which in combining with the lime forms a sulfate, which deposits while the fatty acids rise to the surface.[2]

In the manufacture of ball soda or black ash, salt cake, limestone and coal are mixed together in a reverberatory furnace. The limestone is sometimes soft and chalk-like. Good limestone should have 98% of carbonate of lime.[3]

Palm oils and tallow are the two chief fats bleached by the soapmaker. The color of the latter is sometimes removed by boiling it in lead-lined tanks with a solution of chlorid of lime.

In the saponification of tallow the latter is mixed with good slaked lime into a thin cream with water. This is then inclosed in a suitable vessel, and the whole boiled with steam and agitated for three hours. The action of the lime on the tallow decomposes it, glycerin being set free, while calcium stearate and oleate

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1 Watt. Art of soap-making, p. 128.
2 " " p. 84.
3 " " p. 109.

are formed. The formation of these salts, when mixed together, constitutes an insoluble soap, which is technically called rock, and facilitates the subsequent separation of the solid and liquid constituents of the tallow.

Tanning

In tanning lime is used to remove the hair from the hides, this being done in what are known as lime pits.

Bone-ash

In bone-ash manufacture the lime is employed to precipitate the substances dissolved out of the bones by hydrochloric acid, a fertilizer being obtained as a by-product and known as precipitated phosphate of lime.

Gas manufacture[1]

Lime is sometimes used in the purification of gas from hydrogen sulfid and carbonic acid gas. It can also be used to remove the carbon disulfid when special methods are employed. The lime is prepared in the ordinary manner and converted into hydrate by slaking. In order to get the lime in a fit condition for use however, it should be slaked two or three days before its use, for, if used as soon as formed, it is liable to cake in the purifiers and thus prevent the free passage of the gas through it. Before being placed in the purifiers, it is moistened with water till it attains such a consistency that, when pressed together in the hand, it will pack like snow. It is placed in the purifiers in 4 to 6 inch layers. The removal of CO_2 involves the formation of $CaCO_3$, and when H_2S is extracted, CaS, H_2S is formed. Both reactions may go on at once, but the lime has stronger affinity for the CO_2 than the H_2S.

In gas manufacture lime may be also used to form ammonia from ammonium chlorid or from ammonium carbonate contained in the gas water from the gas works, the reaction being $AmCl + Ca(OH)_2 = 2NH_3 + CaCl_2 + 2H_2O$.

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1 Hornby, J. Gas manufacture, p. 117.

Potassium dichromate

Lime is used in the manufacture of this material, as one of the ingredients of the mixture containing chrome ore, alkaline salts and fuel. The materials are finely ground, mixed and roasted in a furnace, the object of the lime being to prevent fusion and aid in the formation of insoluble chromates. The lime used for this purpose has to be very finely ground to facilitate slaking, and it should furthermore be as free from silica and magnesia as possible.[1]

Paper manufacture[2]

Lime is used in the manufacture of paper to boil the rags in, the object being to get rid of the remaining dirt in them, and also to decompose some glutinous substances, which if allowed to remain would injure the flexibility of the fiber. The quantity of lime employed varies according to its composition and the condition of the rags, but ranges from 5 to 15 pounds to the 100 pounds of rags.

Agricultural uses

Lime is a very beneficial ingredient of the soil, if it is in a condition to be taken up by the plants, that is in a soluble form. Many soils may contain it in the form of silicate, as in feldspar, but till the mineral containing it has decomposed the lime does not become available. Some soils contain sufficient lime for the use of the plants, but in the case of others it has to be added artificially either as an ingredient of manufactured fertilizers or in the form of quicklime.

If the lime is present in the soil in the form of carbonate of lime, it can be detected by the effervescence produced on adding weak acid to the soil. The quantity of lime present in the soil naturally depends on the composition of the parent mass from which the soil was derived, and the climate, whether dry or moist; soils in the former tending to have a much higher per-

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[1] Frasch. Min. ind. 4: 101.
[2] Davis, C. T. Paper manufacture.

centage of lime, because they have been subjected to less leaching action by rainfall.

The advantages of lime agriculturally are great, its effect being both chemical and physical. Physically its action is to cause the soil particles to flocculate, that is to gather together and form compound grains, thus promoting the drainage of the soil, aerating it, and also making it more easily worked. Chemically it serves to hasten decay of the organic matter in the soil as well as that of the mineral particles, and thereby indirectly to facilitate the change of any iron compounds from a ferrous to a ferric condition. It also serves as plant food.

While lime has a stimulating effect on the soil, at the same time it tends to drain it of nourishment more rapidly than would otherwise be the case. The percentage of lime required to produce desirable results in a soil is said to be very small, those with only 1% of the carbonate being often productive.

Pottery glazes

In pottery manufacture lime is used in two different directions: viz in the manufacture of the pottery body, serving as a flux, and as a constituent of the glaze.

Minor uses

Other uses of lime are, for purifying drinking water; as a disinfectant; as a polishing material; for preserving eggs; in dyeing; in the manufacture of calcium carbid; for dehydrating alcohol; in the manufacture of lime pencils for oxyhydrogen lights.

Mortar

Mortar is a mixture of slaked lime and sand used for the purpose of binding masonry together, and more lime is probably used for this purpose than for any other.

The use of lime as a mortar has been known for many years, and the ancients were familiar with the fact that by means of simply burning limestone and soaking the burnt mass in water

they could obtain a stiff paste which possessed valuable properties.

Pure lime has 71.4% calcium and 28.6% oxygen. It is a porous, earthy, white solid, which when pure resists a high degree of heat. It absorbs both moisture and carbonic acid from the air with the greatest avidity.

Richardson gives the following requirements for caustic lime when used for mortar.[1]

Except when made from coarsely crystalline marble or from marl or shells it should be in hard lumps.

It should be white, or nearly so, in color. Lime of a yellow or brownish color with veins of silicious matter is inferior.

It should be free from fused or semi-fused stone which shows over-burning, and from unburnt ash of fuel or clinker.

It should contain less than 10% of impurities but often has more.

It should slake rapidly, showing that it is rich and fresh.

Good lime in lumps should weigh, as packed, with about 40% of voids, 60 lb a cubic foot, 75 lb a bushel, and from 220 to 230 lb per 3 bushels. If ground or in powder, it will weigh less when packed loosely, but when well shaken down it will weigh as much as 270 lb a bbl. A lump of hard lime one foot cube would weigh about 95 lb, having a density of 1.52.

Slaking

Lime combines with water with evolution of heat and every 100 parts of lime takes 32 parts of water. If 33% of its weight in water is sprinkled on lime it heats, cracks open and falls to powder.

The increase in volume in slaking is caused by the expansive force of the steam, but lime may be slaked without increasing its volume by passing dry steam over it in a tube. The energy of

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1 Brickbuilder. 1897. p. 78.

slaking increases with the decrease of impurities. The same lime may show a varying increase in volume in slaking due to amount of water added, etc. The slow addition of water raises less heat, and slaking lime in an open box gives less heat than in a closed one.

With an equal volume of water the increase in size of a rich lime is 2 to 2.4%. Richardson illustrates this point as follows:

Vol. of H_2O	Increase in volume
½	1.6
1	2
2½	2.5
With a poor dolomitic lime it was	
2	1.7

No set rule can therefore be laid down. For instance, 1 peck lump lime with 44% of voids, on slaking with its own volume of water, gave 2¼ pecks of fine powder of slaked lime. From 1 peck of closely packed lime, 2.5 vol. of slaked lime were obtained.

Gilmore found large increases, some running 2.46, 2.83, 3.21, 2.40, but this was caused by his using larger amounts of water than are generally taken in practice.

The following table gives the tests made by both Gilmore and Richardson.

	Rockland Gilmore	Rondout Gilmore	New York Richardson
Weight of lime in pounds	5	5	5
Vol. of lime in cubic centimeters..	1 557	1 806	2 350
Vol. of water required	2 983	3 300	2 000
Increase of weight to slake, in %..	2.24	2.24	1.6
Increase in volume	2.46	2.14	1.91

The theoretic increase is 1.53. Lime also slakes simply on exposure to the air, but this is not good for mortar-making, as the slaking has not been accompanied by any violent disengagement of heat to rupture the mass. The larger particles also have a hardened rim.

Method of slaking

The water may be sprinkled over the lime gradually, or added at once in excess.

The former is best, because a looser mass is obtained, and it gives better results with poorer limes, slaking them more thoroughly. Too great an excess of water tends to lower the temperature and render the slaking incomplete. This causes unslaked particles to get into mortar, and by their subsequent slow hydration and expansion they may do much harm. Popping of mortar is due to this cause. It is also true that, if the water is added gradually, it may allow the mass to cool down. Enough water should be added to allow for that escaping as steam. With very fat lime 2½ vol. of water may be taken. Poor magnesian limes take less.

Pure water should be used. That with soluble salts gives rise to efflorescence, and hence sea water is undesirable, though it has been successfully tried for hydraulic cement. An excess of water gives granular paste and also makes the mortar porous.

After slaking sand is added to the lime to make mortar. According to Gilmore[1] the lime forms silicate, carbonate and hydrate, and the crystals of these compounds interlock with the sand grains, thus binding the whole together into a solid mass. In the course of time all the lime changes to carbonate, but this change may take a number of years.

Sand is added to lime for economy and to prevent shrinkage. Sand should be clean and sharp and should be in such quantity that the lime will fill all the interstices. If an excess of sand is used, the bond is poor. If too little sand is used, the mortar shrinks and cracks. If too little lime is used the paste is made thin. In ordinary sands, the spaces form 30% to 40% of the total volume, and in such 1 vol. paste fills voids of 2½ vol. sand.[2] In practice 1.25 to 2 vol. of sand to 1 of paste is used. This in

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[1] Gilmore. Limes, hydraulic cements and mortars, p. 299.
[2] Brickbuilder. 1897. p. 101.

case of fat lime means 3 to 5 vol. of sand to 1 measured vol. of lime. This gives a plastic mortar which does not crack.

Richardson gives the following mortar experiments.

Composition and physical properties of the lime

Loss on ignition, H_2O and S	1
Insol. SiO_2 and silicates	1.2
Al_2O_3 and Fe_2O_3	.8
MgO	.6
CaO	95.6
	99.2
Weight of cubic feet including voids	60 lb
Voids	44%
Density of lump	1.52

	1	2	3	4	5
Weight of CaO used	1000	1000	1000	1000	1000
Weight of H_2O to slake	1000	2000	2500	3000	4000
Weight of H_2O for paste	1000	500	......	......	....
Vol. of H_2O to one of CaO	2	2.5	2.5	3	4
Vol. of paste	2000	2560	2712	3120	4120
Weight of paste	2720	3280	3392	3880	4850
Density of paste	1.36	1.28	1.25	1.24	1.17
Characteristics of paste	Thick	Thick	Medium	Thin	Very thin
Vol. of sand, moist	2000	3000	5000	7100	14360
Weight of sand	3000	4500	7500	10800	20600
Vol. of sand to lime	2	3	5	7.1	14.4
Vol. of sand to paste	1	1.2	1.8	2.6	3.5
Vol. of mortar	3320	4400	5840	7200	13500
Weight of mortar	5740	7760	10650	13960	25450
Density of mortar	1.73	1.75	1.82	1.94	1.88
Consistency of mortar	Thick	Medium	Medium	Sloppy	Very sloppy
Dries	Cracks	Dries without shrinking			

Percentage composition

	1	2	3	4	5
Water	30	29.3	22.5	20.7	15.1
Sand	52.6	67.9	68.1	72.2	82
Lime	17.4	12.8	9.4	7.1	3.9
	100	100	100	100	100
Return of water to lime	**1.7**	**2.3**	**2.4**	**2.9**	**3.9**

CEMENT

The name cement was formerly applied only to materials which were added to lime mortar in order to make it harden under water. Subsequently this term was used for all combined material which gave a mortar that hardened under water, and so has extended to our natural and Portland cement. Under cement materials are now included hydraulic agents, hydraulic limes, slag cements, natural cements and Portland cements. Hydraulic agents are materials which cause silica and clay to unite with the lime of common mortar, giving us a combination of slow hardening properties. Such hydraulic agents may be natural or they may be artificial. The natural ones are represented by the pozzuolana of Italy, and the trass of the Rhine valley in Germany. In this country they are only known in the far west. The artificial hydraulic agents include slag, burned clay, shales, ashes, silicate of soda or any inorganic material that contains clay and silica in a form permitting its solution in acids.

When the clayey impurities increase in ordinary quicklime, it assumes hydraulic properties and the lime is known as hydraulic. Sand is an impurity which is not too large to prevent slaking but simply retards it. Hydraulic limes with only 5% to 15% of silicates will harden in from eight to 20 days, but with a larger amount in from one to four days. No sharp line can be drawn between true cements and hydraulic limes.

For convenience the following classification is made in this report.

Hydraulic limes

Rosendale cement, or natural rock cement

Portland cement

Hydraulic limes

These generally have 18% to 25% of clay, free silica and combined silica, iron oxid and alumina, sometimes magnesia and alkalis.

The burning of hydraulic lime must be carried on very slowly. The higher the percentage of total silicates, the lower must be the temperature of burning, for under no circumstances should the material be allowed to sinter as it does in the case of Portland cement. Such overburned pieces slake very slowly. Furthermore, the burning should only go to the point of driving off the CO_2. The best hydraulic lime known is the celebrated Chaux du Teil whose composition according to Dr Michaelis is:

Silica	22.588
Alumina	2.629
Iron oxid	.837
Lime	65.624
Magnesia	1.536
Potash	.124
Soda	.065
Sulfuric acid	.523
Ignition	6.424

Hydraulic limes have generally a yellow color. Their specific gravity is about 2.9 and on ignition they lose about 8%. They harden slowly and their hardness by themselves is small. On the other hand if mixed with sand they develop a high degree of tensile strength.

Natural or Rosendale cements

Under this heading are included those made from limestones which have over 20% of aluminous impurities, and which, when burned and finely ground, harden with water in a short time. This includes the Roman cements used abroad, and also the dolomitic cements made from magnesian limestones. They do not develop much heat on mixing with water, and their strength does not equal the artificial or Portland cement. They differ from hydraulic limes in their quicker set, and lower percentage of lime. The following anaylses given by U. Cummings[1] indicate the wide range of materials included under this class. Some authors in fact make two groups of the dolomitic and Roman cement ma-

[1] American cements, p. 35.

terials, which they regard as coequal with Portland. The name, Rosendale, is often given to these cements, because it is the name of the locality at which the natural rock cement beds were first discovered and are best developed in the United States.

Analyses

No.	Silica	Alumina	Iron oxid	Lime	Magnesia	Alkalis	Lime sulfate	Loss on ignition	
1	16.05	1.92	3.22	77.29	1.52	....	....	....	Hydraulic limes Put in for comparison.
2	24.33	3.73	....	71.94	....	....	....	....	
3	29.71	5.35	3.29	59.53	.95	1.17	....	....	
4	20.57	1.13	....	77.76	.54	....	....	....	
5	28.14	9.1	3.2	53.34	1	2.8	....	2.42	
6	27.88	6.19	4.64	56.45	4.84	....	....	....	
7	25.31	7.03	9.74	56.17	1.75	....	....	....	
8	44.5	15	12	8.8	4.7	5.5	....	9.5	
9	48.94	18.75	11.92	6.4	2.42	3.93	....	7.64	
10	24.3	2.61	6.2	39.45	6.16	5.3	....	15.23	
11	34.66	5.1	1	30.24	18	6.16	....	4 84	
12	23.16	6.33	1.71	36.08	20.38	5.27	....	7.07	
13	26.4	6 28	1	45.22	9	4.24	....	7.86	
14	25.28	7.85	1.43	44.65	9.5	4.25	....	7.04	
15	30.5	6.84	2.42	34.38	18	3.98	....	3.78	
16	29.98	6.88	2.5	33 23	17.8	7.1	....	3.13	
17	30.84	7.75	2.11	34.49	17.77	4	....	3.04	
18	27.3	7.14	1.8	35.98	18	6.8	....	2.98	
19	27.98	7.28	1.7	37.59	15	7.96	....	2.49	
20	28.38	11.71	2.29	43.97	2.21	9	....	2.44	
21	19.9	5.92	1.14	46.75	16	8.02	....	2.27	
22	22.62	7.44	1.4	40.68	22	2.23	....	3.63	
23	26.69	7.21	1.3	43.12	19.55	1.13	....	1	
24	24.34	8.56	2.08	61.62	.4	2	....	.8	
25	23.32	6.99	5.97	53.96	7.76	....	....	2	
26	27.6	10.6	.8	33.04	7.26	7.42	....	2	
27	33.42	10.04	6	32.79	9.59	.5	....	7.66	
28	22.58	7.23	3.35	48.18	15	....	....	3.66	
29	22.44	6 7	2	32.73	.67	....	....	35.46	
30	28.43	6.71	1.94	36.31	23.89	1.8	....	.92	
31	17.5	6.5	3	36 51	....	....	....	36.49	
32	22.21	16.48	1.67	39.64	17.5	....	....	2.5	
33	32 06	21.27	2.11	35.56	7	....	....	2	
34	2[illegible].45	2.24	2	5[illegible]	10	....	....	1.31	
35	18.59	9.14	1	40.7	27	....	....	3.57	
36	19 52	1.97	1.29	41.51	1.47	....	....	34.24	
37	28.02	10.2	8.8	41.48	1	.5	....	7	
38	25.15	8	3.23	49.53	13.78	....	....	.26	

SOURCE

1 Hydraulic lime, Aberthaw, Eng.; used in construction of Eddystone lighthouse

2 Hydraulic lime, Lyme Regis, Eng.

3 Eminently hydraulic lime, Holywell, Wales

4 Hydraulic lime, Le Teil, France

5 Hydraulic cement, "King's farm," Susquehanna river, near Williamsport, Pa.

6 Roman cement, Rüdersdorf, Ger.

7 Roman cement, Isle of Sheppy, Eng.

8 Pozzuolana, near Rome, Italy

9 Trass, from the Rhine valley
10 Buffalo hydraulic cement, Buffalo, N. Y.
11 Utica, Ill.
12 Milwaukee, Wis.
13 "Fern leaf" brand, Louisville, Ky.
14 "Hulme," Louisville, Ky.
15 N. L. & C. co., Rosendale, N. Y.
16 "Rock lock" "
17 "N. Y. & R." "
18 "Hoffman" "
19 Norton high falls "
20 Cumberland, Md.
21 Napanee, Ont.
22 "Newman," Akron, N. Y.
23 "Cummings" "
24 South Riverside, Cal.
25 "Brockett," Fort Scott hydraulic, Kansas City, Mo.
26 Utica brand, Utica, Ill.
27 Shepherdstown, W. Va.
28 Howard hydraulic cement, Cement, Ga.
29 Hydraulic cement rock on Platte river, Neb.
30 Mankato, Minn.
31 Cement rock, near Salt Lake City, U.
32 St Louis hydraulic cement, near E. Carondelet, Ill.
33 Barnesville, O.
34 Warnock, O.
35 Austin, Minn.
36 Blacksburg, S. C., cement rock.
37 Round Top cement, Hancock, Md.
38 Balcony Falls, Va.

The Rosendale region of New York is one of the best producers of natural cement (of the dolomitic type) in this country, but hydraulic limestone is found more or less in many states, specially those of the Appalachian region of the east. Others occur in the west and in the region of the Great lakes. Some idea may be gained of the extent of this industry at the present day by stating that the works for making natural hydraulic cements are found in New York, Pennsylvania, Maryland, Virginia, West Virginia, Ohio, Illinois, Kentucky, Minnesota, Kansas, Utah, New Mexico, Wisconsin and Texas. According to the United States geological survey, there were 76 plants in operation in 1899, which produced 9,868,179 barrels of natural cement, worth

$4,814,771. Nearly 50% of this was made in New York by 29 works. In fact it was in New York state that the first natural rock cement in this country was made, and the United States exceeds all other countries of the world in the quantity of natural cement produced.

The following table gives the production in 1899.

Production 1899

	No. of works	Product barrels (300 pounds)	Value
Florida (1898)	1	7 500	7 500
Georgia	1	13 000	9 750
Illinois	3	537 094	187 983
Indiana and Kentucky	19	2 922 453	1 022 858
Kansas	2	150 000	60 000
Maryland	4	362 000	144 800
Minnesota	2	113 986	56 793
New York	29	4 689 167	2 813 500
Ohio	3	34 557	17 279
Pennsylvania	5	511 404	255 702
Tennessee	1	10 000	8 000
Texas	1	12 000	20 400
Virginia	3	63 500	38 100
West Virginia	1	52 727	21 090
Wisconsin	1	396 291	151 992
	76	9 868 179	4 814 771

From the above it is seen that in 1899 natural rock cement was made in 16 states, by 76 firms.

Natural rock cement industry

The first in this country was made from waterlime rock in 1823, its nature being discovered by accident. It was found while the Delaware and Hudson canal was being put through Ulster county, and it was noticed that the lime which was burned from certain strata near Rosendale hardened under water instead of slaking. Similar discoveries followed rapidly at other localities, and as a result waterlime rock was found in western and

central New York, in the Lehigh valley of Pennsylvania, in the James, Potomac, and Ohio river valleys, the result being that natural rock cements were made at all these localities at a comparatively early date.

In 1899 the total production of natural rock cement was 9,868,179 barrels. This was unequaled by any other country, the nearest approach to it being France, with six million to seven million barrels a year of both hydraulic lime and hydraulic cements. The United States is probably in the lead, owing to excellence and abundance of raw materials. The greatest production was in 1892; since then both product and price have decreased, one reason for this being the increase in the Portland cement industry.

The American natural cements are made from argillaceous limestone of varying geologic age. In western New York state they are mostly derived from the waterlime beds at the top of the Salina. Those of the Rosendale region are from the base of the lower Helderberg. In Wisconsin, natural rock cement is made from rocks of Devonian age near Milwaukee; and in Kentucky there is an important cement-producing area near Louisville. In Pennsylvania thick cement beds are found in the Trenton limestone of the Lehigh valley, but magnesian hydraulic limestones are also known in the Carboniferous. In Wisconsin cement rocks are quarried near Milwaukee, belonging to the Hamilton period. In Illinois near Utica and La Salle cement is obtained from the Calciferous limestone. The rocks of Maryland are also Silurian.

The deposits at Rosendale (N. Y.) are perhaps the most important; but those of the Lehigh valley in Pennsylvania are remarkable for their purity and extent.

The hydraulic limestones, or natural rock cements, can be divided into two classes based on the different amounts of carbonate of magnesia which they contain. In one class it does not exceed 3% or 4%, while in another 15% to 35% is found. Most of the hydraulic limestone of the United States is magnesian, but

that found in the Lehigh valley and the upper Potomac is not. Likewise some of the deposits of the west; but it can be said in general that over 90% of the rock used is dolomitic. The Rosendale and the Louisville cements contain 15% to 25% of magnesia. The amount of the two carbonates in the two limestones varies from 54% to 75%, while the silica and the silicates may vary from 20% to 47%. The rock may even vary considerably in one locality, it being sometimes found that certain layers in a quarry make excellent cement, while others are useless or give a product of low grade. A good example of this is furnished by the following analyses quoted by Richardson in the *Brickbuilder,* 1897, p. 152.

Analyses

	1	2	3	4	5	6	7	8	Light 9	Dark 9	10	11
Loss on ignition...	36.56	29.5	41.95	34.82	31.09	39.65	28.55	33.23	37.34	39.64	30.94	38.95
Silica	14.61	23.99	6.68	15.97	21.45	9.89	33.06	20.47	15.01	9.06	19.7	8.01
Alumina and iron												
Insoluble	3.83	5.6	2.03	4.54	4.01	2.77	3.26	5.09	3.22	4.84	4.84	2.63
Soluble	2.49	4.17	1.58	3.05	2.86	2.73	3.26	2.67	5.22	2.51	5.09	1.89
Lime	25.25	20.16	31.59	23.72	23.87	28.63	20.33	26.2	25.85	27.88	20.25	39.77
Magnesia	16.18	13.33	15.81	15.64	12.98	15.15	10.26	11.59	18.84	15.67	15.23	7.43
Sulfur as SO_2......	.78	1.29	trace	.71	.22	.34	.82	.58	trace	.38	.34	.44
Lime carbonate...	45.09	36.01	56.42	42.36	42.63	51.13	36.31	46.79	46.17	49.79	36.16	71.04
Magnesium carbonate...........	33.98	27.99	33.2	32.84	27.26	31.82	21.55	24.34	39.56	32.91	31.98	15.6
Total carbonate...	79.07	64	89.62	75.2	69.89	82.95	57.86	71.13	85.73	82.7	68.14	86.63
Silica etc., coarser than 100 mesh....	9.51	6.92	1.29	.04	......	4.84	.32	1.31	.32	......	2.02	.33

Mr Richardson states as follows:

It was recommended that stratum 1 be rejected, as it contained 9.5% of sand coarser than would pass through an ordinary screen of 100 meshes to the inch. This rock is also too rich in carbonates and would have given, under the best handling, an inferior cement, as magnesium cements deficient in clay are not constant in volume after use.

Stratum 2 had an excellent chemical composition but physically was too coarse, and, lying among inferior strata, it would naturally be rejected for economic reasons.

Stratum 3 was rejected because quite deficient in clay and silica.

Stratum 4 was characterized as a poor rock, which might be used if necessary, but was not recommended, being deficient in clay.

Stratum 5 was marked as being a slight improvement over 4, owing to the smaller amount of carbonates it contained, though deficient in clay.

Stratum 6 was too rich in carbonates and too low in alumina, or clay, to be used for hydraulic cement.

Stratum 7 was the most silicious of the series, though it contained little clay. With care in burning it could be used, as the silica present was in a fine state of division. It is, however, not an entirely satisfactory rock.

Stratum 8 proved a good stone for this quarry.

Stratum 9, in both its light and dark forms, was, besides having great lack of uniformity, too rich in carbonates and deficient in insoluble matter. By itself this stratum would prove a poor one.

Stratum 10 was excellent and recommended for use.

Stratum 11 appeared at a glance to be insufficiently hydraulic and was excluded.

Of all these strata, for one or more reasons, only those numbered, 5, 8, and 10, were considered fairly good rock if burned by themselves. It was possible, however, to mix different strata and thereby obtain a mixture of the proper quality. No. 7 was consequently included, and the cement so prepared analyzed as follows:

Loss on ignition	8.29
Uncombined silica	16.3
Combined silica	13.5
Alumina and iron oxid	11.04
Lime	33.36
Magnesia	15.58
Sulfuric acid	.4
Alkalis	1.5

Another series of hydraulic limestones, which are lacking in magnesia however, are also quoted by Richardson in the article referred to.

These facts emphasize clearly the necessity of thoroughly testing the rock to be used, in advance. Adaptibility for cement depends on the amount of silica and silicates which it contains and also on the percentage of sulfur and alkalis. In addition, the silica should be combined with the alumina, and the rock should also be dense. The two classes of natural cement, viz the magnesian and the non-magnesian, differ distinctly in other properties. The magnesian cements do not heat on mixing and with water they set and strengthen slowly but in the end are as strong as the lime cements. They do not resist frost well when first used, and often careful preparations have a tendency to expand a year or two after use. The lime cements, even after being carefully manufactured, have a tendency when made into mortar to heat, on the one hand, when too rich in lime and, on the other hand, to bloat when too rich in silicates or overburned. They acquire strength rapidly, having nearly as great a tensile strength at the end of from one to 28 days as the magnesian cements. They resist frost better than the latter but are at times inferior, more brittle and crystalline, with a tendency to deteriorate in strength. The perfectly prepared and carefully made cements of this class are the best natural cements in the world. The Round Top cement of the Potomac valley is typical of the highest grade of the lime cements, as the numerous Rosendale brands are of the magnesian class.

Physical properties

Of primary importance is the density of the rock. A light rock does not burn well and may not give a cement of suitable volume, weight or density. The specific gravity at 78° F should not be below 2.7, and preferably be 2.8. Some stones used have a specific gravity of only 2.65, but they are inferior. The best rock is obtained from those portions of the quarry which are

beyond the range of weathering. Richardson gives the following density for the Rosendale rock.

Nearest surface	
Light rock	2.83
Dark rock	2.849
Medium	
Light rock	2.815
Dark rock	2.841
Light rock.	2.827
Dark rock	2.845

The Fort Scott (Kan.) rock which is nearer the surface has a density according to Mr Richardson of only 2.73, the Round Top rock, Maryland, is 2.731, the hydraulic limestone of Illinois is only 2.667 and does not produce as dense a cement. It is also desirable that the various ingredients of the rock should be as thoroughly mixed in as possible. If the sand is coarse or the clay in lumps or the carbonate in pockets by itself, the rock is not adapted for making cement. Generally mere inspection will supply information on this point, and the size of the particles can be determined by dissolving a weighed fragment in acid and determining the size and quantity of the insoluble particles of sand remaining. The residue of the Rosendale rock found at various depths is noted by Richardson as follows.

Per cent of residue on sieve	200 mesh	100 mesh	50 mesh
Nearest surface			
Light rock	...	2.9	...
Dark rock	...	...	...
Medium			
Light rock.	...	...	...
Dark rock	...	...	...
Deepest			
Light rock.	.6	.6	.4
Dark rock.	1.2	.5	.3

On treatment with acids, the rock retains its shape, but the clay is dissolved out, and the residue can then be broken down with the fingers. If a coarse rock must be used, the burning should be slow in order to give a combination between the lime and silica every possible chance to take place.

Manufacture

The process of manufacture of this class of cements is comparatively simple. The rock as it comes from the quarry is usually broken into lumps of head size before being charged into the kiln.

The kilns in use in New York state are similar to those used for burning lime (pl. 3). The old type kilns are made of stone, with the interior either round, oval or rectangular in cross-section, and lined with fire brick. They are open at the top, and taper at the bottom to an opening, through which the burned stone is discharged. When the material is not being drawn, this hole is sometimes kept covered by grate bars.

At Akron (N. Y.) the kilns have an interior area of 9 x 22 feet, or when round a diameter of 9 feet. The hight of all is 34 feet.

The more modern kilns are cylindric in shape, made of boiler iron. They are from 40–45 feet high and lined with fire brick.

In burning natural cement rock, the fire is first started with wood in the bottom of the kiln, and on this are spread alternating layers of coal and rock. The coal is of pea or chestnut size commonly. As the burned stone is drawn from the bottom, fresh stone and fuel are added at the top. The kilns are commonly built on a hillside, or where the ground is flat, five, six or more in a row, and in either case tracks are laid on the top to facilitate the delivery of the stone and fuel. The yield of these kilns is large, being from 50–120 barrels of cement[1] per ton of coal. Some patented forms with the Campbell grate, such as is used

[1] Min. ind. 2: 104.

at Milwaukee, give more uniform product and also use less fuel (pl. 7).

When the material is drawn from the bottom, it is commonly sorted into normally burned rock, overburned or clinkered material, and underburned stone. At some works the clinker is retained and treated separately; for, though it is of much greater hardness than the normally burned stone, and requires more powerful machinery to crush it, still it possesses a much higher tensile strength. Three works in this state pulverize this clinker and put it on the market under the name of Portland cement.

There is usually a track running along the base of the kilns, on which the cars are brought to receive the calcined stone. These cars are then run up to the grinding rooms, where the rock is reduced to powder. Several types of crushers and pulverizers are used, including Gates and Blake crushers, Steadman disintegrators, Sturtevant burstone and emery mills, Cummings pulverizers, etc.

The burned stone usually goes through a gradual process of reduction, necessitating the use of machines for coarse, medium and fine grinding, and the types used as well as their arrangement is slightly different at each works, as will be seen by reference to the description of the New York industry given in subsequent pages. In the natural cement trade there are several standards of weight per barrel, as follows: Rosendale, 300 pounds net; Pennsylvania, 280 pounds net in barrels, 200 pounds net in sacks; Western standard, 268 pounds net.[1]

The Sturtevant roll jaw crusher (pl. 8) contains two steel jaws with curved faces, pivoted at their lower end. The jaws are operated by means of a toggle joint. It is claimed that this crusher takes rocks of large size and reduces them at one operation to gravel and sand. A crusher with 6 x 16 jaws weighs 7 tons, and requires 10 horse power to run it. Its capacity is asserted to be 3 tons an hour of Portland clinker, when set to $\frac{1}{4}$ inch opening.

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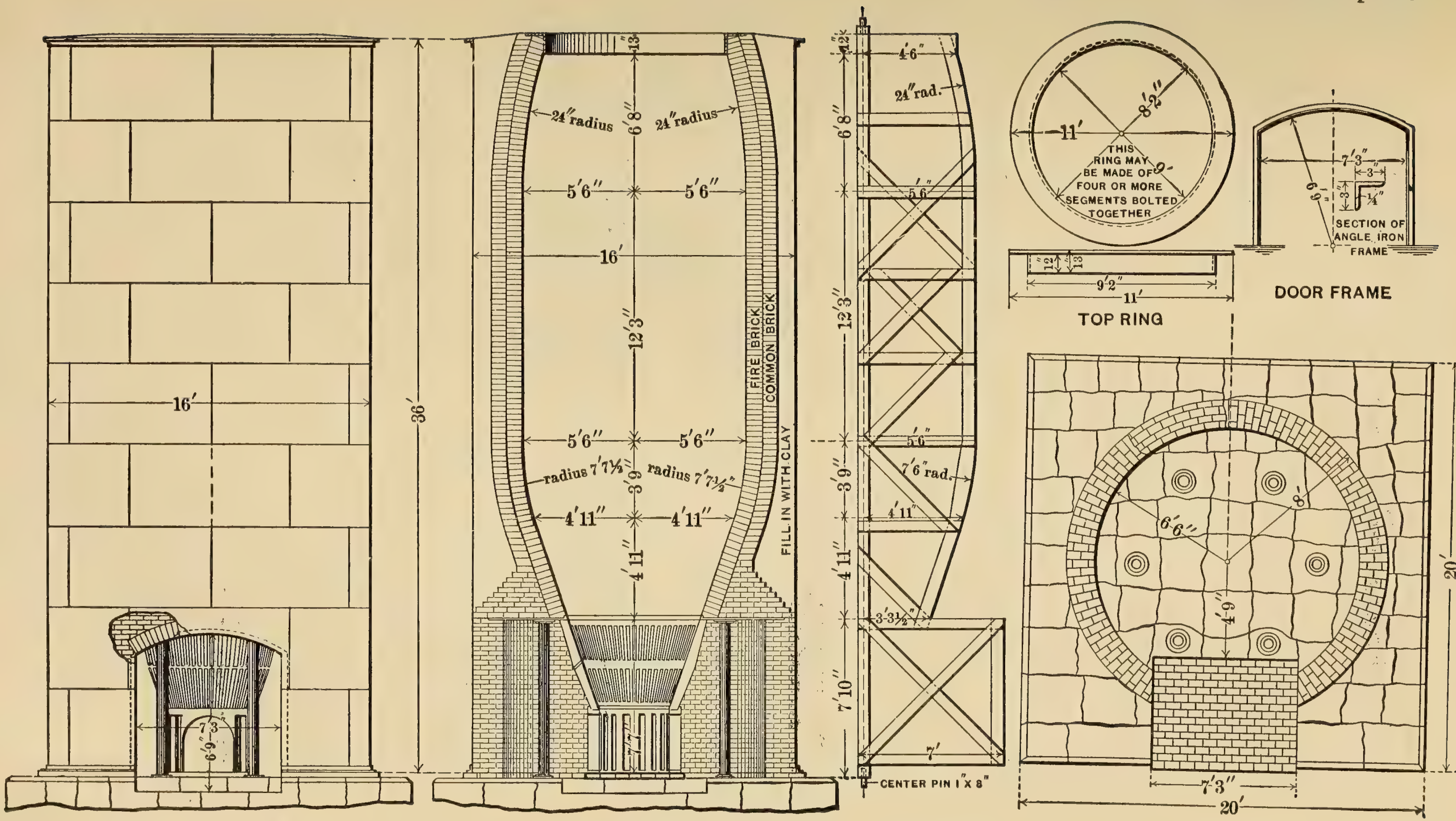
[1] Min. ind. 6: 104.

Plate 7

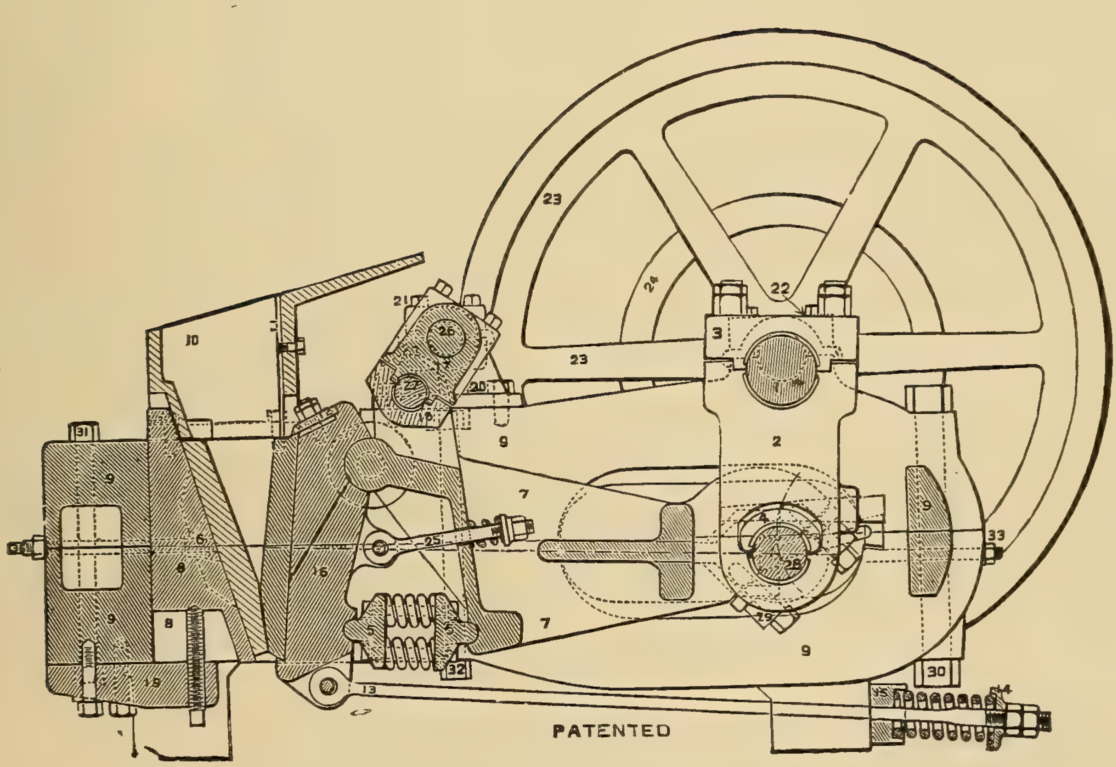
To face p. 688



FRONT ELEVATION. SECTION. TEMPLATE. TOP RING. DOOR FRAME. PLAN.

Kiln for burning natural rock cement, equipped with Campbell grate (Mineral industry, 6:105)

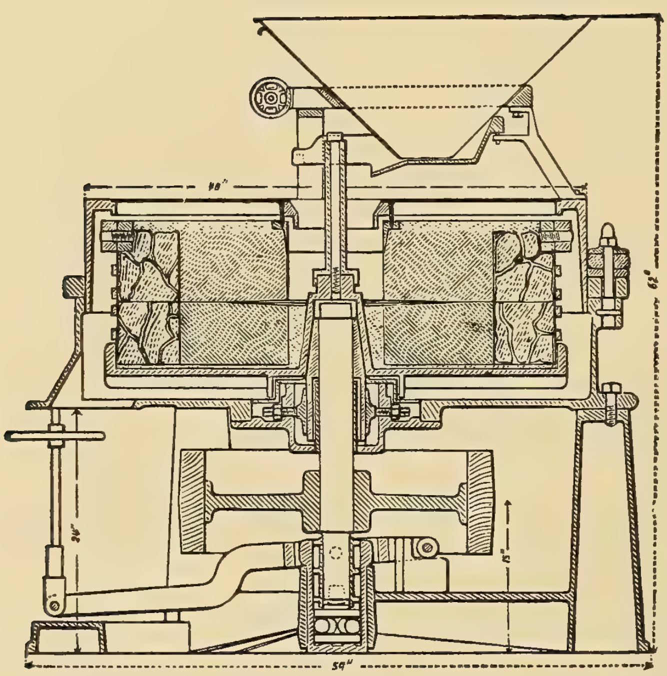
Plate 8 To face p. 688



Vertical section of Sturtevant roll jaw crusher

Plate 9

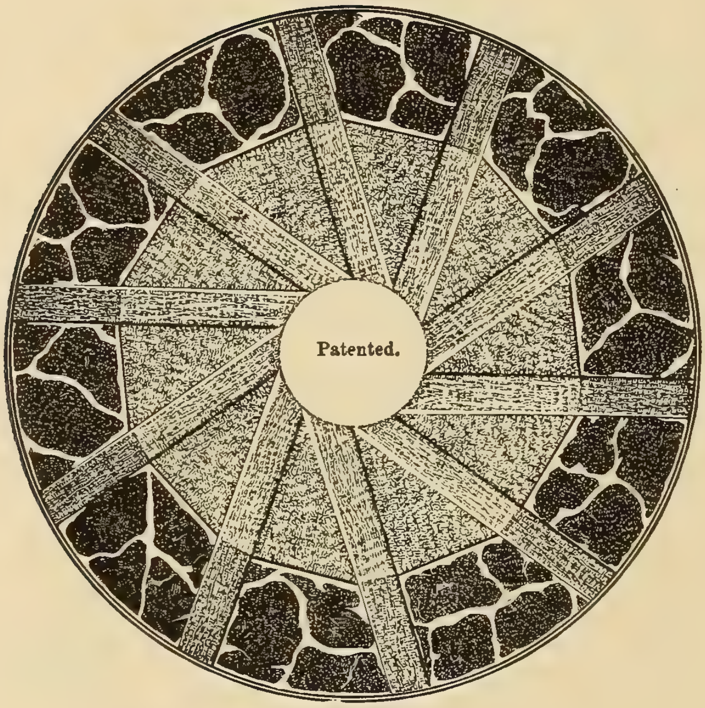
To face p. 689



Vertical section of Sturtevant emery mill

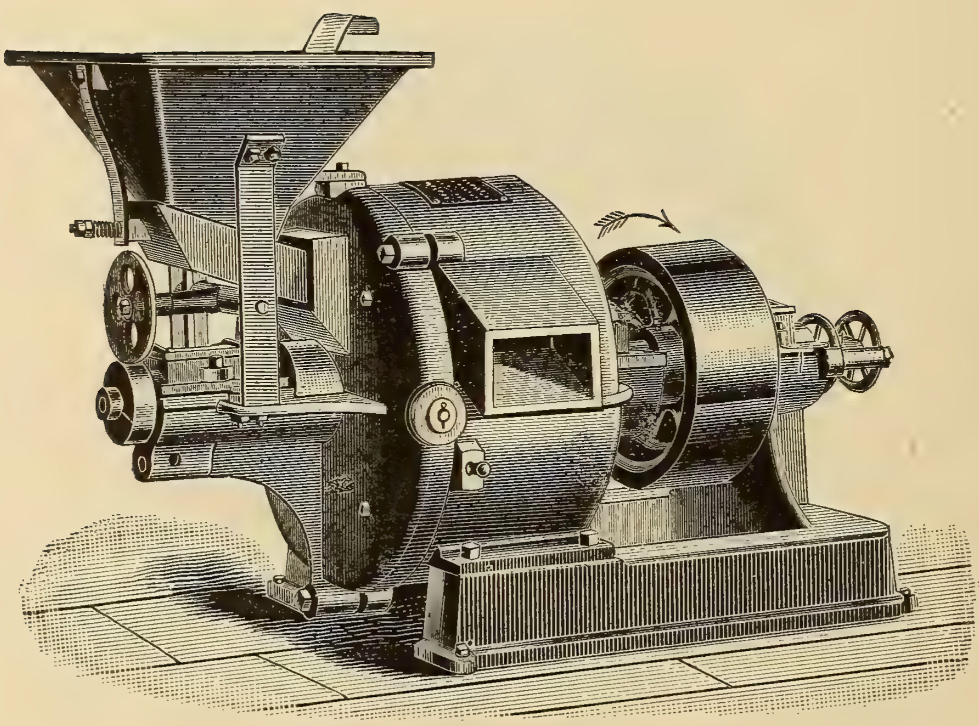
Plate 10

To face p. 689



Sturtevant emery mill stone

Plate 11 To face p. 689



Sturtevant disintegrator, used for grinding cement

The emery millstones of Sturtevant type are seen at many cement works. They consist of two millstones, with emery on the surface. The millstones are in each mill and are set in a horizontal plane. The bedstone is bolted in place, while the upper stone is set to revolve with the minimum amount of vibration. The lower stone is adjustable (pl. 9, 10).

The size of the mill is expressed in the diameter of the stone. The mills come in 36 and 42 inch size. A 42 inch size will grind on the average 5–6 barrels of Portland an hour, when working on crushed clinker. About 95% of the product from the millstones will pass a 100 mesh sieve.

The same machines grind from 18–20 barrels an hour of rock cement. These machines require from 15–18 horse power to operate them.

The Stedman disintegrator represents a type of mill in which the pulverization of the particles is produced by their being thrown violently against each other as the machine revolves. The machine which is shown in pl. 11, consists of several concentric drums, alternate ones revolving in the same direction, at a high rate of speed and represents a similar disintegrator of Sturtevant make.

These machines are said to be very efficient till the unequal wear of parts disturbs their balance, after which they deteriorate rapidly unless the worn parts are renewed.

Chemical composition

The amount of carbonate in each hydraulic limestone must not exceed 75% and preferably is under 70%, and, where the quarry contains several strata of different richness, it is possible to bring about the proper composition by mixing. Hydraulic limestones free from magnesia, it is claimed, give the best results provided they contain enough clay. The Maryland rock with 68.44% of lime carbonate and only 4.58% of magnesia, but with silica and clay amounting to 29.66%, is an example of this kind. In any single rock the amount of magnesia should not exceed

40% and should preferably be less than 25%. A stone with more than the latter amount has a tendency to expand slowly with age, specially if it runs low in clay. A western New York rock with 37% of carbonate of magnesia and less than 2% of silica and silicates is an example of this fact. The Rosendale cements contain only about 20% of magnesian carbonate with 30% of clay. The amount of silica and silicates present is highly important, for they influence the hydraulic properties of the limestone, and, as said before, the silica should be in combination with the alumina. This is determined partly from the quantity of alumina contained in the stone. For example, two stones, one from Akron (N. Y.) and the other from the Rosendale region, show according to Richardson respectively 35% and 29% of insoluble material; but, from the amount of alumina and iron present, we can see that there is very little clay in the Akron stone, while there is much of it in the Rosendale rock, the former having only 4.84% of alumina and iron, while the other has 10%. The Rosendale in consequence makes a very superior cement, while the Akron shows the qualities resulting from a deficiency in clay but an excess of magnesia. The effect of this deficiency in clay is to form a cement which heats and sets too quickly, but an excess of clay can also be injurious, as already stated.

Sulfur, when found in the limestone, is generally in the form of gypsum (sulfate of lime) or pyrites (iron sulfid) but both of these substances are seldom present in sufficient amounts to be injurious. They may occasionally become reduced in burning when combined with iron oxid to produce a green color. Alkalis such as potash and soda are harmless unless present in more than 2%; an excess of them makes the rock fusible, and such material has to be rejected. The following alkali percentages, in different natural rock cement, are given by Richardson.

Milwaukee, K_2O	.87
Milwaukee, Na_2O	1.64
Fort Scott, K_2O	.7
Fort Scott, Na_2O	1.33

Akron, Star, K_2O	1.39
Akron, Star, Na_2O	.23
Akron, Obelisk, K_2O	1.6
Akron, Obelisk, Na_2O	.52
Buffalo, K_2O	1.44
Buffalo, Na_2O.	.41

These alkalis are probably derived from feldspar grains in the clay.

Richardson makes the following subdivisions of natural cements, based on the examination of those made in various parts of the United States.[1]

1 Lime cement with only 2% or 3% of magnesia, 13% to 15% of iron and aluminum oxid, and 20% of combined silica.

2 Lime cements with as little magnesia but with less silicates than class 1, and consequently less satisfactory and more fiery.

3 Magnesia cements with a maximum of not more than 15% of magnesia, the same amount of iron and aluminum oxid and 15% to 20% of combined silica, and, in addition, considerable uncombined silicates, as they are not thoroughly burned.

4 Magnesia cement with a large amount of magnesia, viz over 20%, less alumina and iron and less undecomposed silicates than in the preceding class.

5 Magnesia cement deficient in alumina and iron oxids as well as in combined silica.

6 Magnesia cements thoroughly burned, made from rock having a smaller amount of silicates than those of class four, with only a medium per cent of magnesia and little uncombined silicates.

Cements of the first class set and acquire strength rapidly and increase in this direction for a long period, but the final result is a more brittle mortar than is obtained with the magnesia brands. This class includes the lime cements of the Potomac valley. According to Richardson, the second class has not as variable a

[1] Brickbuilder. Jan. 1898. p. 14.

relation of silicates to lime, and consequently the cements are apt to be fiery and not as satisfactory. They are shown to improve by the addition of Portland cement, after which they can be used quite successfully. This class includes those of the Lehigh valley. The third class is represented by the best Rosendale brands, which set and acquire strength slowly, but which continue to develop it for a long time and eventually are very strong and tough. The fourth class includes cements like those of western New York, which have been, while containing an unusual amount of magnesia, burned so hard that little of the silicates remains undecomposed and uncombined with the lime and magnesia, and in consequence they are apt to stand a long time after use, unless carefully hydrated. The fifth class is one in which the cement is essentially a lightly burned, highly magnesian material in the preparation of which the heat has not been sufficiently high or prolonged to bring the greater portion of the silica in composition with the lime or magnesia, in this respect being in contrast to the preceding class. The hydraulic principle and strength are therefore largely due to the magnesia and carbonates rather than to the silicates and aluminates. Examples of this are those cements made at La Salle (Ill.) The last class gives a cement in which there is rather less magnesia than in the two preceding classes, and less aluminum and iron oxid than in the third class. Though they are burned so thoroughly that there is but a small per cent of silicates uncombined, still, as Mr Richardson says, all of these cements will when properly burned and carefully handled give successful results in the large majority of cases. As a rule natural cement mortars will acquire a satisfactory strength with sufficient time, though it may have originally been very weak, or subjected to unfavorable influences due to the conditions under which it was used.

Portland cement

Portland cement is a hydraulic cement, in which the percentage of lime to alumina and silica is about as 2 to 1. It sets rapidly

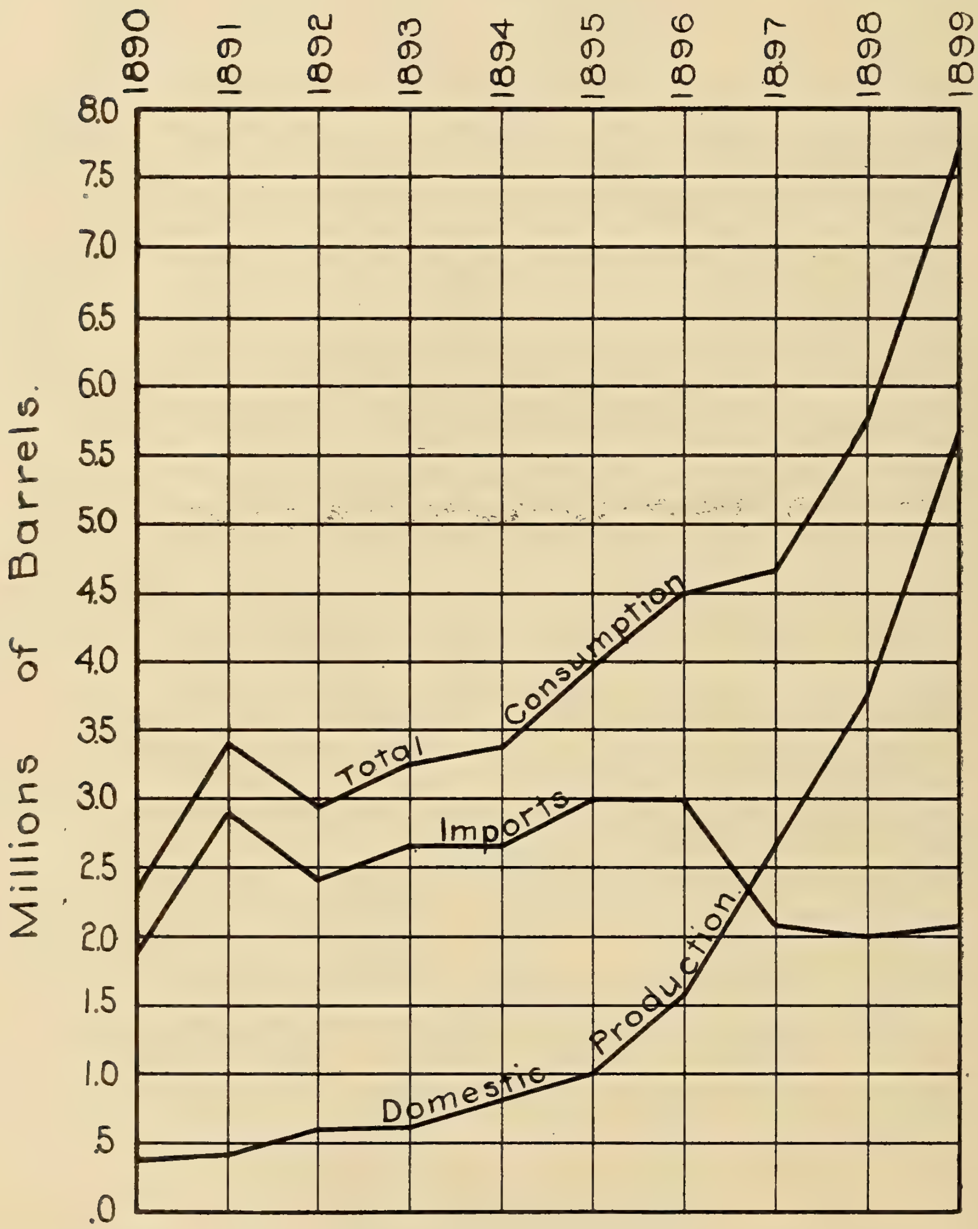


Diagram showing production, imports, and consumption of Portland cement in United States (From U. S. geol. survey. 21st report of director)

as compared with hydraulic limes, and differs from the Rosendale type of cements in developing a much higher tensile strength, and being invariably very low in magnesia.

Portland cement was discovered by Joseph Apsdin, of Leeds (Eng.), who desired to make an artificial cement that would replace natural hydraulic cements. It received its name because it hardened under water to a mass resembling Portland stone.

With very few exceptions, Portland cements are artificial mixtures, and many of the so-called "natural" Portland cements made in the United States and Germany are not strictly such.

The use of hydraulic cement is very old; still the Portland cement industry has been developed entirely in the present century. In this country it is widespread and active, but the output is not large enough to supply the home markets, for the growth of the Portland cement industry has been greatest abroad up to the last three or four years.

In England Portland cement is made chiefly in the Thames and Medway districts, where white and gray chalks and river mud are used. In Germany the Portland cement industry is developed chiefly in the northern part of the empire, the region about Stettin and the Rhine valley being important centers of production. In these localities the materials used are chiefly chalks and marls which are mixed with clay. In southern Germany and Austria as well as Switzerland hard limes are used, in northern France marls, chalks and clays are the materials employed.

The enormous development of the Portland cement industry in the United States, as well as the amount of material used, both native and foreign, may be judged from the following table, which gives the production of Portland cement in the United States from 1891 to 1898 inclusive and also the imports for these years. These imports include shipments from Germany, Belgium, France, England and Denmark.

The statistics are taken from the volume, *Mineral resources, 21st ann. rep't United States geol. sur.* (*see* pl. 12).

Production in United States

	1891	1893	1895	1896	1897	1898
Home production	454 813	590 652	990 324	1 543 023	2 667 775	3 692 284
Imports	2 988 313	2 674 149	2 997 395	2 989 597	2 090 594	2 013 818
Total	3 443 126	3 264 801	3 987 719	4 532 620	4 758 369	5 706 102
Exports	....	14 276	83 682	53 466	53 466	36 732

This shows that the total consumption has increased between 30% and 40%, and that this increase has been supplied mostly by American factories, the imports having remained nearly stationary. It will be noticed that in 1893 the United States also began to export some Portland cement.

Production by states 1899

State	Number of works	Product, barrels	Value not including packages
Arkansas	1	50 000	$87 500
California	1	60 000	120 000
Illinois	2	53 000	79 500
Indiana		None in 1899	
Maryland		"	
Michigan	4	342 566	513 849
New Jersey	2	892 167	1 338 250
New Mexico	1	1 500	4 500
New York	7	472 386	708 579
North Dakota	1	1 700	5 100
Ohio	6	480 982	721 473
Pennsylvania	9	3 217 965	4 290 620
South Dakota	1	35 000	70 000
Texas		None in 1899	
Utah	1	45 000	135 000
	36	5 652 266	$8 074 371

The uses of Portland cement are daily increasing, those now important including: concrete, for river improvement and canal work, culverts and bridge abutments, sidewalks, masonry. In this connection the following remarks of Prof. S. B. Newberry may be quoted.

American cements have largely replaced foreign brands throughout the U. S. This is especially true of English and Belgian cements, which are generally inferior to the best German brands. There is no difficulty whatever at present in selling a good American Portland cement in St Louis and Chicago at a higher price than any well-known English cement; nevertheless the fact remains that there is among contractors a considerable prejudice in favor of certain brands of German cements, and the latter still command a higher price than the American. This prejudice is unfounded, and is therefore certain to depart in time, but it still exists. American cements can be made at a price which will allow them to be sold cheaper than the best imported German, and, where the two come together in competition on large contracts, the work is generally made to the American manufacturers on the basis of price. This was clearly shown on the letting of a large government contract at Pittsburg last winter. The offers were as follows:

1 Belgian cement	$2.50	a barrel
5 German cements, average price....	$2.66	"
4 American cements, average price...	$2.28	"

The price of Portland cement is steadily coming down, and the fall is being hastened greatly by the successful competition of American against foreign manufacturers. There can be no doubt that with a very few years practically all the Portland cement consumed in this country will be of domestic manufacture. The prices of some brands, however, will hardly be the same as they are now. When the demand is completely supplied by American manufacturers, we shall have works in this country producing 2000 barrels per day more than in Germany, and the same result will be reached here as in Germany, namely the complete replacement of the common natural cement rock cements by artificial Portland.[1]

Portland cement industry

Portland cement was first manufactured experimentally in this country at Coplay, Lehigh co. Pa., in 1872 at a locality in which natural rock cement had up to that time been made. A second one was at Wampum, Lawrence co. Pa., where fossiliferous limestone and clay were used.

[1] Newberry, S. B. Brickbuilder. 1897. p. 108.

According to Lewis[1] the principal Portland cement plants in operation in the United States in 1897 together with their dates of establishment were:

Company	Brand	Locality	Established
Coplay cem. co	Saylors, Commercial	Coplay Pa.	1875
J. K. Shinn & Bro	Wampum	Wampum Pa.	1876
Millen & Sons	Millen	South Bend Ind.	1877
Millen & Sons	Millen	Wayland N. Y.	1891
Amer. cem. co	Giant and Egypt	Egypt Pa.	1884
Amer. cem. co	Giant	Jordan N. Y.	1891
Emp. port. cem. co	Empire	Warner N. Y.	1886
Atlas cem. co	Atlas	Coplay Pa.	1889
Alpha port. cem. co	Alpha	Whitaker N. J.	1891, *a* '94
West. port. cem. co	Western	Yankton S. D.	1890
Buckeye cem. co	Buckeye	Bellefontaine O.	1892
Sandusky cem. co	Medusa	Sandusky O.	1893
Diam. port. cem. co	Diamond	Middlebranch O.	1893, *a* '97
Bonneville cem. co	Star	Siegfrieds Br. Pa.	1894
Vulcanite cem. co	Vulcanite	Vulcanite N. J.	1895
Glens Falls cem. co	Iron Clad	Glens Falls N. Y.	1895
Bronson port. cem. co	Bronson	Bronson Mich.	1897
White Cliffs port. cem. co	Setter	Whitecliff Ark.	1897

a Rebuilt.

Additional works have been started at Coldwater and Union City (Mich.), Smiths Landing (N. Y.), La Salle (Ill.), Litchfield (Ky.), and besides these there are several smaller ones. According to Mr Lewis the total capacity of the American works is about 3,000,000 barrels, of which 70% comes from the Lehigh valley region of western Pennsylvania and eastern New Jersey.

Composition of American Portland cements

The American Portland cements are made from a variety of materials which resemble each other chemically rather than geologically. As the cement is made from artificial mixtures, it is frequently possible to use many different grades of limestone and clay-bearing rocks. Though Portland cement is made at many places and from material of widely different character, Portland cement materials are not so very numerous. The alumina and silica are commonly supplied by clay, sometimes shale; and the lime carbonate from limestone or marl.

According to the United States geological survey,[2] the number of factories using limestone or marl is as follows.

[1] Min. ind. 6: 94.
[2] 20th an. rep't. U. S. geol. sur. pt 6, p 545.

	1897 No.	1897 Product, bbl.	1898 No.	1898 Product, bbl.
Factories using limestone...	18	2 282 126	20	3 112 492
Factories using marl	11	395 649	11	579 792
	29	2 677 775	31	3 692 284

The essential elements of Portland cement are calcium, silica and alumina. The first is generally supplied by limestones or marl, the two latter by clay. In burning these three elements unite to form silicates of a complex nature, and it is essential that they be combined in proper proportion in order to give the best results. Faija claims[1] that the lime may vary from 58% to 64%; the silica from 18% to 24%; the alumina and iron from 8% to 14%.

In rare instances it is possible to find a natural limestone which contains the three essential elements in the proper proportion. With marl the expense of crushing and grinding the material is saved, but both have their advantages as well as their disadvantages. The chemistry of Portland has been most carefully studied by S. B. and W. B. Newberry[2] who come to the following conclusions.

1 The essential constituents of Portland cement are tricalcic silicate with varying amounts of dicalcic aluminate. The composition is therefore expressed by the formula $X\ (3CaO,SiO_2) + Y\ (2CaO,Al_2O_3)$. From this the proportion is calculated, that is, lime by weight $= 2.8\ SiO_2 + 1.1\ Al_2O_3$.

2 Fe_2O_3 combines with lime at a high heat and acts like the alumina in promoting the combination of the silica and calcium. For practical purposes the presence of ferric oxid in clay is not to be considered.

3 Alkalis, judging from the behavior of soda, are of no value in promoting the combination of calcium and silica and probably play no part in the formation of cement.

[1] Trans. Am. soc. civ. eng. 30: 43.
[2] Cem. and eng. news. 1898. 4: 5.

4 Magnesia possesses strong hydraulic properties when ignited alone but has none when heated with silica, alumina and clay, and probably plays no part in the formation of cement. It will not replace lime in mixtures, the composition of which should be calculated on the basis of lime only, without regard to the magnesia present.

Using the formula previously given they made up and tested cements as shown below.[1]

	R. Ca to Silicates	CaO	SiO_2	Al_2O_3	Pat. test	Hot test	Tens. str. ¼sq in. section 7 days	28days
Silicate 95 8, Aluminate 4.2	2.67	72.79	25.21	2	Set hard, sound, on glass	Sound, off glass, hard	154	173
Silicate 91.6, Aluminate .4	2.57	71.9	24.1	4	Set hard, sound, on glass	Sound, off glass, hard	148	227
Silicate 85.3, Aluminate 14.7	2.39	70.55	22.45	7	Set hard, sound, off glass	Sound on glass	180	205
Silicate 74.8, Aluminate 25.2	2.15	68.31	19.69	12	Set quick, sound, off glass	Sound, on glass, hard	105	84

The actual composition of some leading cements on the market is given below.

Calcium silicates

Formula	R.Ca to SiA	CaO	SiO_2	Pat. test.	Hot test
2 Ca SiO	1.85	65.11	34.89	Set hard, hard 7 days, hard 6 weeks	Sound, on glass, hard
2½CaO1 SiO_2	2.33	70	30	Set soft, fairly hard 7 days, hard 6 weeks	"
3 CaO SiO_2	2.8	73.68	26 32	Set soft, fairly hard days, hard 6 weeks	"
3½CaO SiO_2	3.27	76.56	23.44	Cracked soft 1 day, hard 6 weeks	"

Dr Michaelis considers that in good Portland cement the ratio of the total silicates to the lime should be about as one to two, and that the variation from this ratio should only be within narrow limits. Cements rich in lime set more slowly, but harden better than those poor in lime. Cements rich in silica generally set slower than those rich in alumina but the former harden very energetically in the beginning and are better for use under salt water. According to Dr Michaelis[2] the celebrated German Portland cement manufactured at Stettin in Germany has a silica percentage of nearly 25 with 5.7% of alumina and 2.5% of ferric oxid.

A material like the limestone of Teil is for instance admirably suited for the manufacture of Portland cement to be used in

[1] Cem. and eng. news. 1897. v. 3, no. 6, p. 85.

[2] Schoch. Die moderne aufbereitung und wertung der mörtel materialien, p. 85.

marine work; its composition is: silica 24; alumina 2.8; ferric oxid .9; lime 70.

Schoch expresses the opposite opinion to Newberry, and considers that alkalis act as a flux, and they can be replaced by calcined soda. He also states that they are of great benefit in connection with the hardening process of cement, as they convert the silica into a soluble form, in which condition it combines with the lime when wet.

An addition of $\frac{1}{2}\%$ to $\frac{3}{4}\%$ of fluorspar is very beneficial for bringing about an easy clinkering of the materials. Nearly all cements contain some magnesia and sulfur, which come originally either from the clay or from the fuel used. Redgrave[1] states that all mixtures containing 77% of carbonate of lime will, when sufficiently calcined, give Portland cement of fair quality. Compounds with too much clay fuse too easily, and the resulting cement is light in weight, sets quickly, has a brownish color and never becomes thoroughly hard.[2] It moreover crumbles when exposed to the weather. Overlimed cements, that is where the part made of lime in the slurry ranges above 77% or 78%, give a cement which will stand the hottest fire without fusing.

Such cements when burned are slow setting and hard to grind, and Portland cement made from such mixtures is liable to flow and swell.

In Europe the clay is generally mixed with marl or chalk, but in this country comparatively little marl is used. In this country Prof. S. B. Newberry[3] gives 17 works as mixing limestone with the clay, and seven using marl, and of the latter four are in New York state.

Marl is cheaper to use for the manufacture of Portland cement, as it is softer and finer grained and consequently needs little grinding. It always has a large percentage of moisture which must be expelled.

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[1] Redgrave. Calcareous cements.
[2] " p. 39.
[3] Mineral resources of U. S. 16th an. rep't U. S. geol. sur. 4: 515.

Redgrave gives the following analyses of English Portland cement mixtures.

1 Mixture made at Folkestone from gray chalk and gault clay

2 Forest of Dean limestone and clay

3 Mixture from Barrow lias quarries

All dried at 100° C, but 2 and 3 have perhaps also lost some H_2O.

	1	2	3
Sand	2.5	5.57	2.58
Silica	11.83	9.61	11.41
Ferric oxid	1.97	2.42	2.34
Alumina	5.23	3.45	4.8
Iron pyrites	tr.	.....	.43
$CaCO_3$	74.18	75.89	74.09
MgCO	1.29	1.5	2.61
$CaSO_3$	.18	.16	.21
K_2O	.9	.88	.93
Na_2O	.31	.39	.46
H_2O	1.82	.61	.43

A clay or Medway mud from Gillingham is as follows:

SiO_2	38.413	Sand
Al and Fe	1.856	
SiO_2	25.249	Hyd. silicates
Al_2O_3	14.244	
Fe_2O_3	6.744	
CaO	.81	
MgO	1.727	
K_2O	2.957	
Na_2O	.773	
H_2O	3.384	
Pyrite	.214	

The clay used for cement should not contain an excess of sand or iron. Clays low in iron are usually of a gray or blue color and light yellow on weathering. The clay should be fairly silicious, and the more amorphous silica present the better. Michaelis[1] gives the following typical examples.

[1] Hydraulischer mörtel u. Portland-cemente, p. 99.

	1	2	3	4	5	6
SiO_2	60.06	59.25	60	62.48	68.45	54.72
Al_2O_3	17.79	23.12	22.22	20	11.64	24.27
Fe_2O_3	7.08	8.53	8.99	7.33	14.8	7.64
CaO	9.92	.....	4.18	6.3	.75	1.89
MgO	1.89	2.8	1.6	1.16	.....	.....
K_2O	2.5	1.87	1.49	1.74	1.9	.....
Na_2O	.73	1.6	.72	.37	2.1	.....
$CaSO_4$	.6	2.73	.89	.60	.....	.....

1 Province of Saxony
2 Vorpommern
3 Oberharz
4 Brandenburg
5, 6 Medway

In most of the European cements the lime runs from 60% to 65%, while in the American it seldom exceeds 63%. In the French and Belgian cements the sulfuric acid is low, in order that they may comply with the engineer's specifications. The Portland cements made in the eastern United States generally show more magnesia than the western ones. The maximum percentage of this material in American is about 4%, while in the European it is 2.5%. Magnesia was formerly considered very objectionable, but opinion is now receding on this point. Those American brands containing 4% of magnesia are not shown to be at all inferior.

In the various numbers of the *Thonindustrie zeitung* for 1897 and 1898, that is vol. 21 and 22, will be found a number of articles and discussions concerning the effect of magnesia in Portland cement. Elaborate experiments of R. Dyckerhoff abroad have not shown any injurious effects to come from 4% MgO. Many American manufacturers adulterate cement by adding sulfate of lime. This generally acts as a diluent, and it should always be stated when it is done.

The raw materials used in the manufacture of Portland cement may sometimes contain sulfate of lime in the form of the mineral gypsum, or sulfur may be present in the form of pyrite, which in burning tends to react with some of the carbonate of lime, yielding calcium sulfate. A similar effect may be caused if there

is much sulfur in the fuel used. The effect of this sulfate of lime, if it does not exceed 2% or 3%, is to greatly delay the setting of the cement and also increase its final strength somewhat. If present to the extent of 4% or 5%, however, both these qualities disappear, since the formation of calcic sulfid is brought about, which in turn reacts with the iron compounds in the cement and tends to disintegrate it. The effect of sulfate of lime is shown in the accompanying table, taken from Prof. Johnson's work, *Materials of construction* (p. 187).

The German association of Portland cement manufacturers has declared against any addition except up to the 2% $CaSO_4$ to regulate setting time. It is the general practice in the United States now to put in 2% $CaSO_4$ to produce slow set.

The following experiments are quoted by Lewis, showing the effect of sulfate of lime on the rate of setting.[1]

NO.	ONE SORT OF CEMENT	SETTING TIME	NEAT-CEMENT BRIQUET					BRIQ. 1 CEMENT, 3 SAND				
			7 days	28 days	12 weeks	25 weeks	1 year	7 days	23 days	12 weeks	25 weeks	1 year
1	As manufactured	0° 20′	323	405	518	620	700	115	168	238	302	360
2	Same w. .5% gypsum	3° 30′	315	456	572	623	650	142	212	339	353	390
3	.1% "	10° 0′	375	508	568	695	780	159	238	311	368	384
4	.2% "	14° 0′	423	543	688	718	805	180	263	305	375	410
5	No gyp. but kept in store for some months	10° 30′	318	450	550	592	618	168	218	3 8	360	431

Results reported by John Grant in 1880.[2]

MIXTURE	7 days	31 days	60 days	90 days
1–1 briq. average of 5	107	159	188	267
1–1 briq. w. H_2SO_4 added to water; average of 5	129	227	260	255

Results reported by Prof. Tetmajer in 1894.[3]

[1] Min. ind. 6: 101.
[2] " 6: 89, 90.
[3] Mitth. d. Aus zur Prüfung v. baumaterialien. 1894. 7 hfte, p. 39.

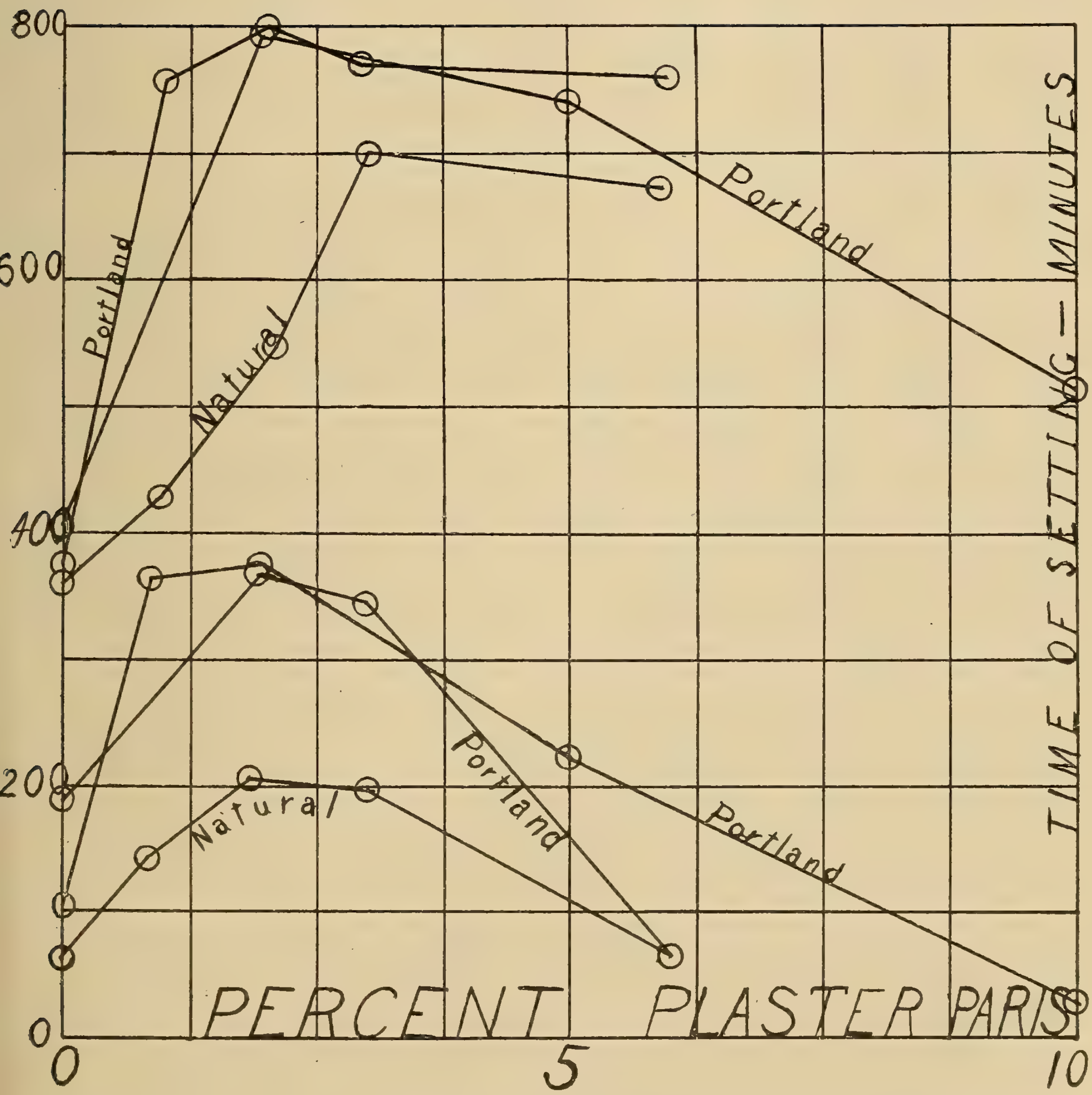

Diagram after Johnson, showing effect of lime sulfate on rate of setting of natural and Portland cement

No.	Per cent of plaster paris added	Strength of sand briq. 1-3 lb. per sq. in. 3 days	7 days	28 days
4	...	...	160	240
	1	...	212	298
	2	...	167	254
5	...	174	285	307
	.5	225	305	344
	1	227	320	408
	1.5	230	381	399
	2	182	290	400
	2.5	184	295	390
	3	115	235	360

Results of Candlot in 1891.[1]

MORTAR	Days	SULFATE LIME 0% lb	1%	2%	3%	4
Neat cem. briq.	7	485	645	533	435	264
	28	673	738	674	790	483
1 cem. to 3 sand briq.	7	223	252	263	185	126
	28	333	377	377	367	201

Lewis considers these results remarkable as regards strength and not explained.

Cements high in alumina have a tendency to expand and to blow or to check. Magnesia is also supposed to cause expansion after a lapse of a considerable interval, while sulfates are looked on as causes of disintegration of Portland cement when exposed to sea water. Cements low in lime and without an excess of alumina but high in silica are simply of low strength like under-burned cements. If the alumina goes above 8%, it is considered high, if below 5%, it is considered very low. Mr Richardson considers that over 3% of magnesia is an excessive and undesirable quantity, and the proper limit for sulfuric acid is 1½%. The following are the percentages of magnesia and sulfuric acid in Portland cements which have been placed on American markets during the past few years.

[1] Ciments et chaux hydrauliques. Paris 1891. p. 254.

MgO	SO_3	MgO	SO_3
.86	1.25	2.84	1.53
2.79	1.71	1.16	2.71
1.81	1.24	2.73	1.51
1.45	1.1	1.85	1.39
1.68	1.5	1.32	1.32
2.48	1.36		

American raw materials used in the manufacture of Portland cement also show a great variation in their composition, as will be seen from the following table of analyses taken in part from *Mineral industry,* 6: 97, and from the volumes on mineral resources in the annual reports of the director of United States geological survey.

Analyses of raw materials

	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	$CaSO_4$	SO_3	Ins.	H_2O & Org.
Lehigh val. Pa. cem. rock	14.68	5.32	1.12	69.26	.....	3.67	.....	2.29	.....	.....	1.68*b*
Lehigh val. Pa. cem. rock	15.4	4.26	1.38	74.66	.....	2.66	.....	.86	.....	.....	1.88*b*
Lehigh val. Pa. limestone	5.87	1.59		88	.....	4	.....	.....	.....	...	— *c*
Lehigh val. Pa. cem. mixt.	13.97	5.07	1.88	74.1	.....	2.04	.....	.....	.....	.....	1.82*b*
Lawrence co. Pa. limes'ne	4.14	.21	1.77	90.47	.....	1	.....	.....	.....	.....	2.03*b*
Warren co. N. J. cem. mixt.	14.16	6.64		73.96	....	3.13	.....	....	.....	.....	*c*
Glens Falls limestone ...	3.3	1.3		....	52.15	....	1.58	.....	.3	*a*	8.37
Glens Falls clay.........	55.27	28.15		....	5.84	....	2.25	.....	.12	.....	....
Warner marl	.26	.1		94.39	.....	.38	....	....	.....	....	4.64*c*
Warner clay	40.48	20.95		25.8	.....	.99	.....		.....	...	8.50*c*
Sandusky marl	......	1.72		92.7	.....	.53	....	2.06	.....	1.28	1.13*c*
Sandusky clay...........	64.7	11.9	9.9	....	.9	....	.7	......	.....	.....	11.90*c*
Bronson marl	1.65	...	.81	90.66	.....	tr.	.....	......	.66	.....	5.59*c*
Bronson clay	62.1	20.09	7.81	......	.65	....	.96	......	.49	.....	7.90*c*
Yankton chalk	2.15	2.72		93.72	.....	....	.....	.....	.....	....	*c*
Yankton chalk	8.2	7.07		83.59	.....	....	.....	......	...	.....	*c*
Yankton clay	57.98	18.26	4.57	...	1.75	....	1.83	......	1.28	.....	12.08*c*
Arkansas chalk	4.42	2.21	1.03	95.29	.....	....	.....	....	.....	.....	*d*
Arkansas chalk..........	6.09	3.52	1.2	87.93	.....	....	1.06	......	.....	.....	*d*
Arkansas clay...........	53.3	23.29	9.52	....	.36	....	1.49	......	.....	.....	5.16*d*
Arkansas clay...........	65.12	19.05	7.66	....	.34	....	.31	......	.....	.....	6.12*d*
La Salle Ill. limestone...	8.2	1.3		88.16	.....	1.78	....	.....	...	.....	......
La Salle Ill. clay........	54.3	19.33	5.57	....	3.29	......	2.57	.....	2.36	.....	......
Litchfield Ky. limestone	.49	tr.	.22	97.63	....	.65	....	......	.34	.....	......
Litchfield Ky. clay......	55.82	19.77	6.19	....	.7	......	.....	....	.....	.....	....
Harpers O. marl........	.....	1.15	....	82.66	.....	1.92	.....	.45	.....	7.28	6.54
Syracuse Ind. marl.....	......	1.21	....	88.49	...	2.71	.....	1.58	.....	1.78	4.23
Wellston O. limestone ..	3.53	1.14		....	54.45	....	.44	......	.....	38.74	*e*
Wellston O. clay.........	69.49	16.42		....	2.29	....	.78	......	.....	5.43	......

a CO_2 46.98. *b* Pa. geol. sur. *c* Mfr's anal. *d* Branner. Proc. Am. inst. mining. eng. *e* Loss on ign.

The following additional analyses are also taken from the *Mineral industry,* 6 : 97 and 99.

European materials

	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	Ins.	Ign.
English white chalk, from	.66	....	.35	98.6	......	.21	......	......	*a*
to	1.59	....	.74	97.9	......	.1	......	......	*a*
English gray chalk, from	1.67	.93	.38	96.5	......	.5	......	......	*a*
to	6.84	1.14	.46	87.35	......	.1	......	......	*a*
English cement slurry	11.77	4.45	2.13	69.97	......	2.87	......	1.24	7.59*a*
English cement slurry ...	11.83	5 23	1.97	74.18	......	1.29	......	2 53	1.82*b*
English Medway clay..............	63.66	16.1	6 74	....	.81	....	1 73	......	3.38*c*
English Tyne clay..	55.83	23.04	7.78	....	......	2.57	......	......	*b*
								SO	
German Hamburg chalk	1.55	....	.5	97.5	......	....	.19	.2	*d*
German Hamburg clay	52.5	17.35	5.75	....	4.48	....	3.24	.91	14 *d*
German Stettin marl	19.7	3.66	1.34	73.92	......	.97	......	.32	*d*
German Stettin clay	54.6	18.2	5.4	....	2.8	....	3.16	.99	13.1 *d*
German Rhine limestone	3	.42	.53	94.5	....	....	.86	.13	*d*
German Rhine clay.	[illegible]0.7	19.13	8.37	....	2.63	....	3.20	1.64	13.4 *d*
Belgian Beerse clay	65.5	18.55	6.01	....	.38	....	1.18	.14	*e*
" Visé chalk.	1.42	5.77		96.8	......	.45	......	......	*e*

American cements

BRAND	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	AUTHORITY
Alpha	22 62	8.76	2.66	61.46	2.92	1.53	Bootle, G. B.
Atlas	21 96	8.29	2.67	60.56	3.43	1.43	"
Giant	19 92	9.83	2.63	60.32	3.12	1.13	"
Saylors	22.68	6.71	2.35	62.3	3.14	1.88	"
Vulcanite	21.08	7.86	2.48	63.68	2.62	1.25	"
Empire	22.04	6.45	3.41	60.92	3.53	2.73	"
Jordan	21.86	7.17	3.73	61.14	2.34	1.94	"
Diamond	21.8	7.95	4.95	61.9	1.64	.79	"
Sandusky	23.08	6.16	2.9	62.38	1.21	1 66	"
Bronson	20.95	9.74	3.12	63.17	.75	.86	Mfr's. anal.
Whitecliffs	22.93	10.33		64 67	.94	1.05	"

a Heath. *b* Redgrave. *c* Stanger and Blount. *d* Candlot. *e* Michaelis.

European cements

Brand	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Authority
White label Alsen	20.48	7.23	3.88	64.3	1.76	2.46	B. G. B.
Dyckerhoff	20 61	7.15	3.69	63.06	2 33	1 39	"
Germania	22.08	6.84	3.36	63.72	1.32	1 82	"
Hemmoor	21.14	5 95	4.01	63.24	1.44	1.47	"
Lagerdorfer	23.55	7.47	2.4	61 99	1.42	1.07	"
Brook, Shoobridge co	22 2	7.35	4.77	61.46	1.35	1 87	"
Francis	22.18	8.48	5.08	61 44	1.34	1 56	"
Condor	23.87	6.91	2.27	64.49	1.04	.83	"
Candlot Fr	22.3	8.5	3.1	62.8	.45	.7	Candlot
Boulogne Fr	22.3	7	2.5	64.62	1.04	.75	"

Manufacture of Portland cement

The steps usually followed are preparation of the raw materials, mixing, burning, grinding and bolting.

In Portland cement manufacture there are two general methods of preparation, the aim of each being to mix thoroughly the raw materials. These methods are known as wet and dry methods. In the wet method proper the materials are mixed by forming them into a thin paste with water, after which they are dried before burning. In the dry method only enough water is used to permit forming the materials into bricks, so that they can be charged into the kiln. A modification of the dry method consists in grinding the material dry and charging it in this manner into the rotary furnace, or mixing only enough water to make it ball.

Wet process. The raw materials best adapted to this method are soft chalk and plastic clay, which on account of their condition can be easily mixed with water. The material has sometimes to be reduced to a powder by means of crushers, but this is not always necessary, and the mixing is done in water. It is the custom at some works to give the material a preliminary mixing by spreading it in alternating layers of chalk and clay on the floor, and, when it is removed to the washing mill, digging into it vertically.

The wash mills in which the mixing is done consist of several different forms, but they are essentially cylindric tanks, some-

times of masonry, at others of wood, the usual diameter being 20 feet and the depth 6 feet to 7 feet. In the center of the tank is a masonry pier, which supports a revolving vertical shaft, which carries the wooden frame with the scrapers. This is driven by means of a rack and pinion. Such a mill makes about 20 revolutions a minute, and sometimes the materials are put through twice in succession to insure a thorough mixing, enough water being added to keep the whole in suspension. If the water has to be evaporated, then it is best to use as little as possible. Water is continually added during the stirring, and, as it overflows, it passes off through chutes to the backs. These chutes also serve the purpose of arresting any sand that the material may contain.

One of the disadvantages is that, owing to differences in specific gravity of the clay and chalk, they may settle with different rapidity. This can be guarded against by repeated testings. It is claimed by some[1] that the wet process does not mix the materials as thoroughly as the dry method, specially where limestone is used.

Another disadvantage is the time required to dry, and also the floor space needed.

Dry method. In this method the raw materials are ground dry separately, after which they are mixed, and then wet up to a paste known as slurry, which is molded into slabs or bricks to facilitate charging it into the kiln. This method of preparation may be used in connection with any type of kiln except the rotary one, for in this case there is no need of forming the slurry into cakes of any kind. At some works a dry press instead of a stiff mud machine is used to mold the bricks.

Burning. After the raw materials have been thoroughly mixed they are burned to a condition of incipient vitrification. According to the type of kiln used, the mixture is charged in either the wet or dry condition. The changes which take place in burning are of great importance, for on their proper manipulation depends

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[1] Gary, M. Trans. Am. soc. civ. eng. 1893. 30: 3.

the quality of the manufactured product. These changes are three in number, i. e. driving off of the mechanically combined water; driving off the carbonic acid; fusing together of the silica, alumina, lime and iron. Each of these requires a different temperature for its accomplishment, but the attainment of the proper temperature to produce the last change is the most important. If the required temperature is overstepped, the cement is overburned and has little or no setting power.

Specific gravity. The specific gravity of the Portland cement is often an indication of the thoroughness of the burning, and is determinable by some form of pycnometer.

One type consists of a flask with a stopper, and having a long graduated neck. The vessel is filled with benzin or turpentine up to the zero graduation on the tube. A given weight of cement is dropped into the tube, care being taken to allow all the air bubbles to escape, when the rise of the liquid in the tube indicates the volume of cement added. If metric units have been used, then the specific gravity of the cement is equal to the weight of the quantity added in grams divided by the increase in volume in cubic centimeters.

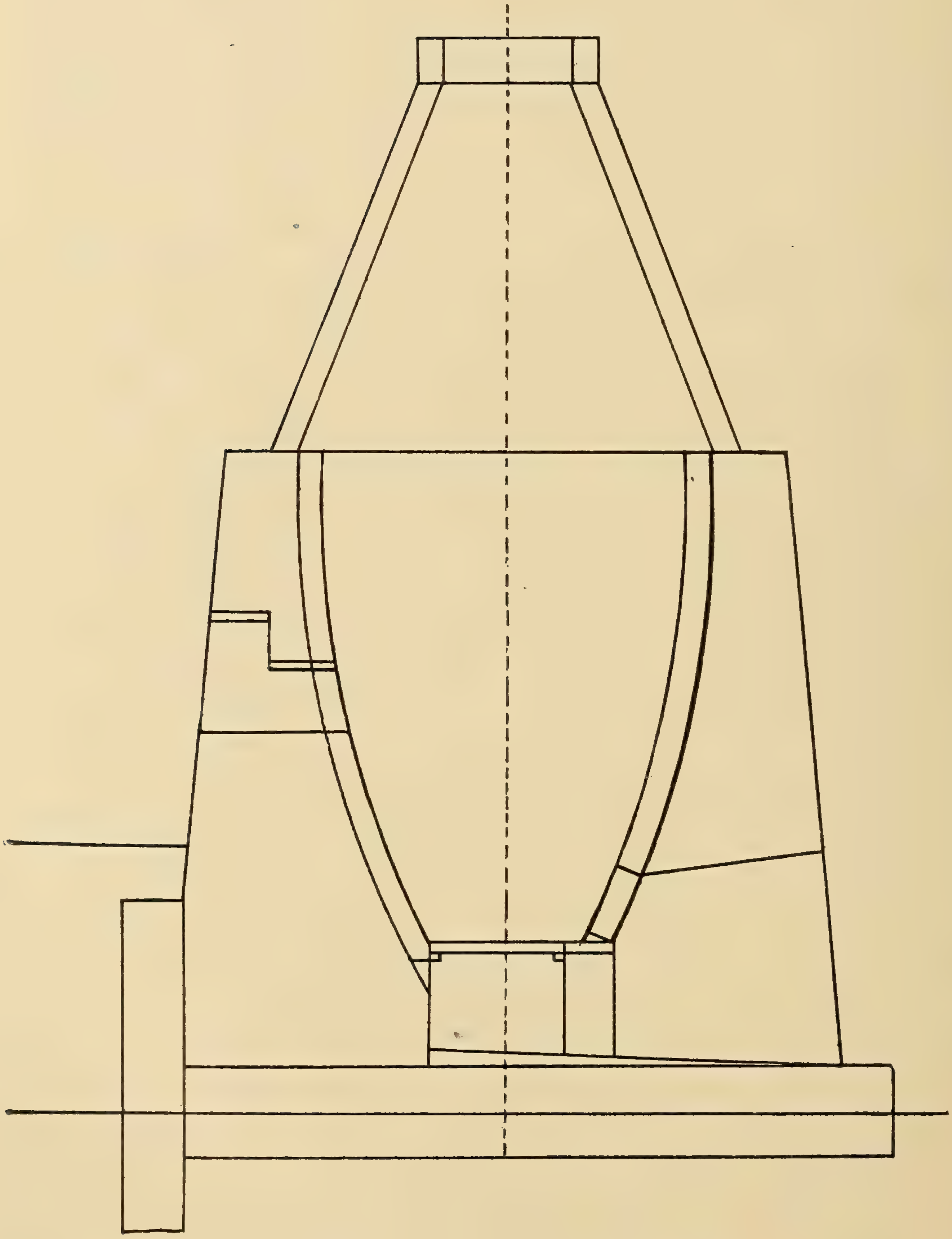
Well burned Portland cement has a specific gravity of more than 3.05, but should not exceed 3.15 or 3.20.

In making this test it is necessary to see that there are no lumps, and that the cement is thoroughly dried.

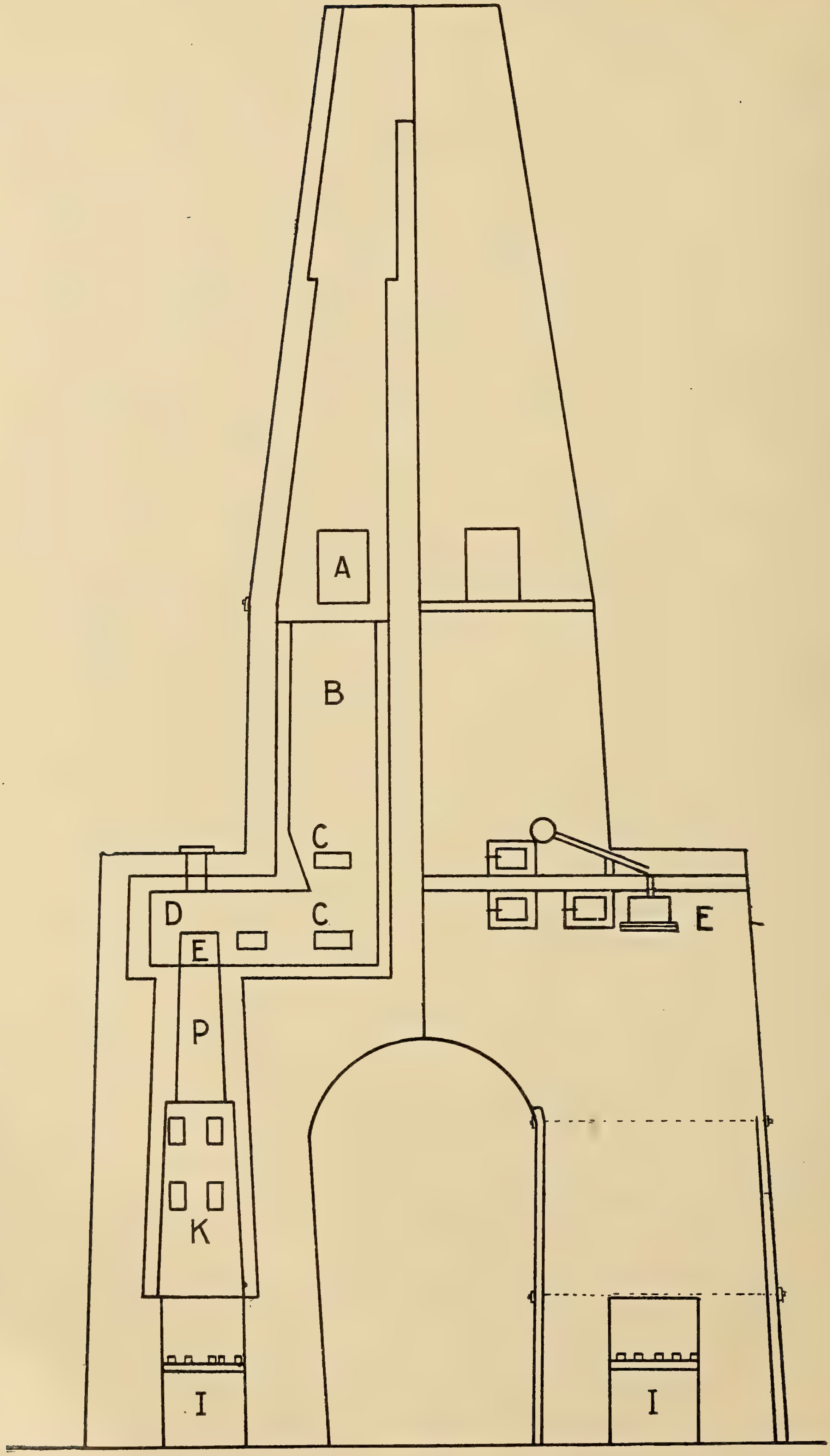
Kilns. The types of kilns used in the United States are: intermittent or dome kilns; continuous kilns, of Dietzsch or Shöfer type; rotary furnace.

In the old-fashioned intermittent kiln the bricks of cement and coke are charged in alternate layers. The Dietzsch and Shöfer kilns are continuous, as already stated, and possess the great advantages of cheaper fuel, economy of labor, and of burning the dry, powdered material. The rotary furnace effects an enormous saving of time and labor, and it is claimed that the temperature can be regulated far more exactly than is possible in

To face p. 709



Dome type of kiln, after Butler



Dietzsch kiln, after Butler

the older processes. Crude or fuel oil is used at all the American factories where this type of furnace is employed. Producer gas could no doubt be employed. It is claimed by Johnson that this type of kiln is used only at those works where the mixed materials will not adhere with sufficient firmness to permit molding into bricks.

Dome kiln (pl. 14). This is one of the oldest types used, and is the simplest. The kiln is charged by placing kindling at the bottom, and then alternate layers of coal and slurry cake are put on, till the kiln is full enough. The fire is then started, and burns slowly upward through the mass, the temperature gradually increasing. The doors at the bottom are then opened and the clinkers discharged through them. The kiln is recharged for another burning. The recharging occurs about once in a week or 10 days. The proportion of underburned and overburned clinker depends on the relative amount of fuel and slurry used. As fuel burns out, fresh material can be added at the top, or the whole mass can be allowed to burn out and be removed without recharging the kiln. There is much waste heat, which is sometimes utilized for drying the slurry, but the utilization of this should in no way interfere with the working of the kiln.

When the kiln is intermittent in its action, there is of course a great loss in heat. There is probably also much cost for repairs, as the heating and cooling tend to crack the walls. This kiln is rather expensive in fuel and produces an output averaging only 3 to 6 tons of cement a day in a month's run. A good deal of sorting and picking of the clinker is required to exclude the underburnt and vitrified material. Till 1889 these were the only kilns in this country.

Dietzsch kiln (pl. 15). This is continuous in its action, and has been in use in some works for a number of years being patented in 1884. The fuel used in it is generally coal slack, and the cost of calcination, comparing this with the "bottle" kiln is small, but the slurry has to be dried before introduction, and there is

no available waste heat for this purpose. The working part of the kiln is divisible into three sections, viz, a heating, a burning, and a cooling chamber.

Butler describes it as follows:[1] (*see* pl. 15)

Supposing the kiln to be in operation, the cooling chamber H would be filled with calcined clinker, which is being cooled by the cold air passing through it on its way to the burning chamber F. The cooling chamber thus serves the double purpose of cooling the clinker and giving its heat to the entering air.

The burning chamber is filled with slurry.

The heating chamber B is filled with slurry, which is introduced at A. At fixed intervals, generally about every half hour, a certain portion of the clinker is drawn out at the bottom, which causes a general downward movement of the mass throughout the kiln, while a fresh portion of the slurry heated by the escaping gases is raked forward into the calcining chamber, the necessary fuel being added through the eyes EE.

It sometimes happens that, owing to the clinker being slightly overburned and vitrifying too much, the mass hangs up, and will not drop properly when a portion is drawn from the bottom; to overcome this difficulty, eyes are placed at convenient levels at the lower end of the calcining chamber, so that, with the aid of iron bars, the mass may be detached and again set in motion.

This kiln is said to be very economical in fuel consumption. It however requires constant attention and charging. The labor is great compared with that compelled by the common intermittent kiln, and it has to be watched carefully, so that much of the success in burning depends on the skill of the burner. Butler claims that it yields a large percentage of unburned slurry.

Newberry[2] claims great economy of fuel for the Schöfer type of kiln, specially its modified form, the Aalborg. Only about two tons of soft coal a day are required for each kiln, with a daily production of 75–80 barrels of cement clinker. This is only about 12% of the weight of the clinker produced, and with coal at $2 a ton corresponds to a cost for fuel of only 5c for each barrel of cement produced.

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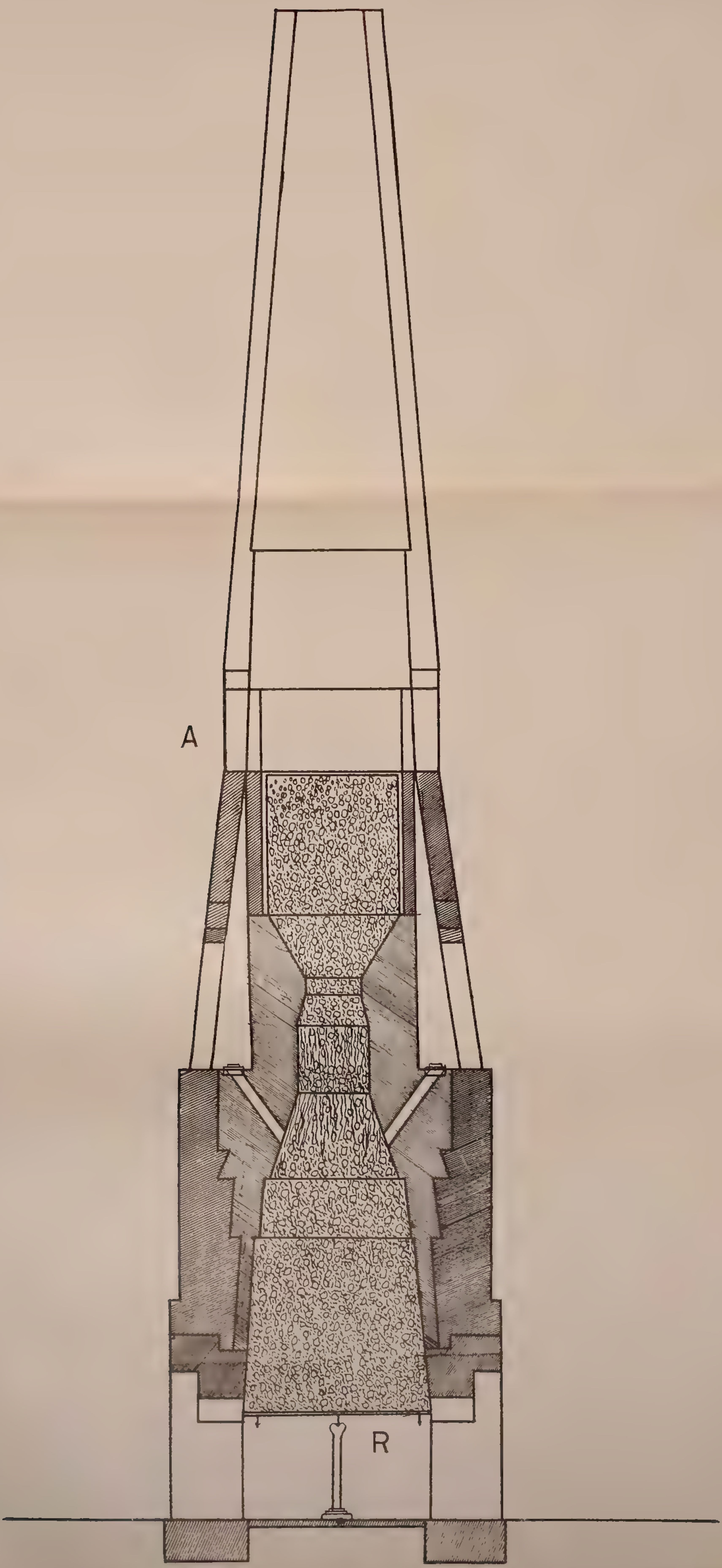
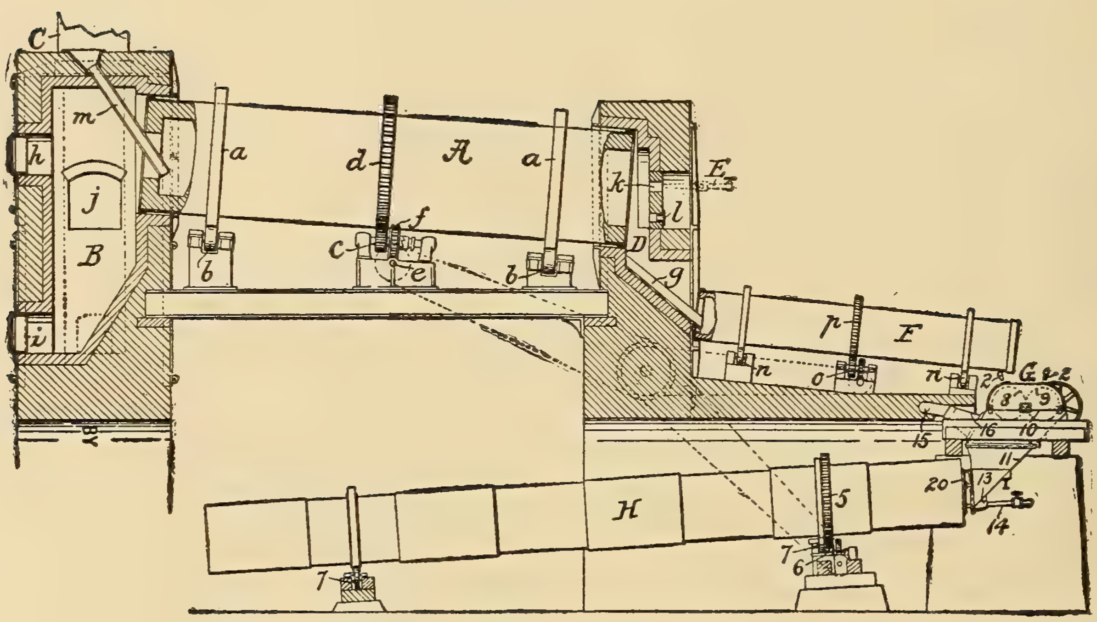
1 Butler, D. B. Portland cement.

2 18th an. rep't U. S. geol. sur. pt 5, p. 1176.



Section of Schöfer kiln, after Schoch

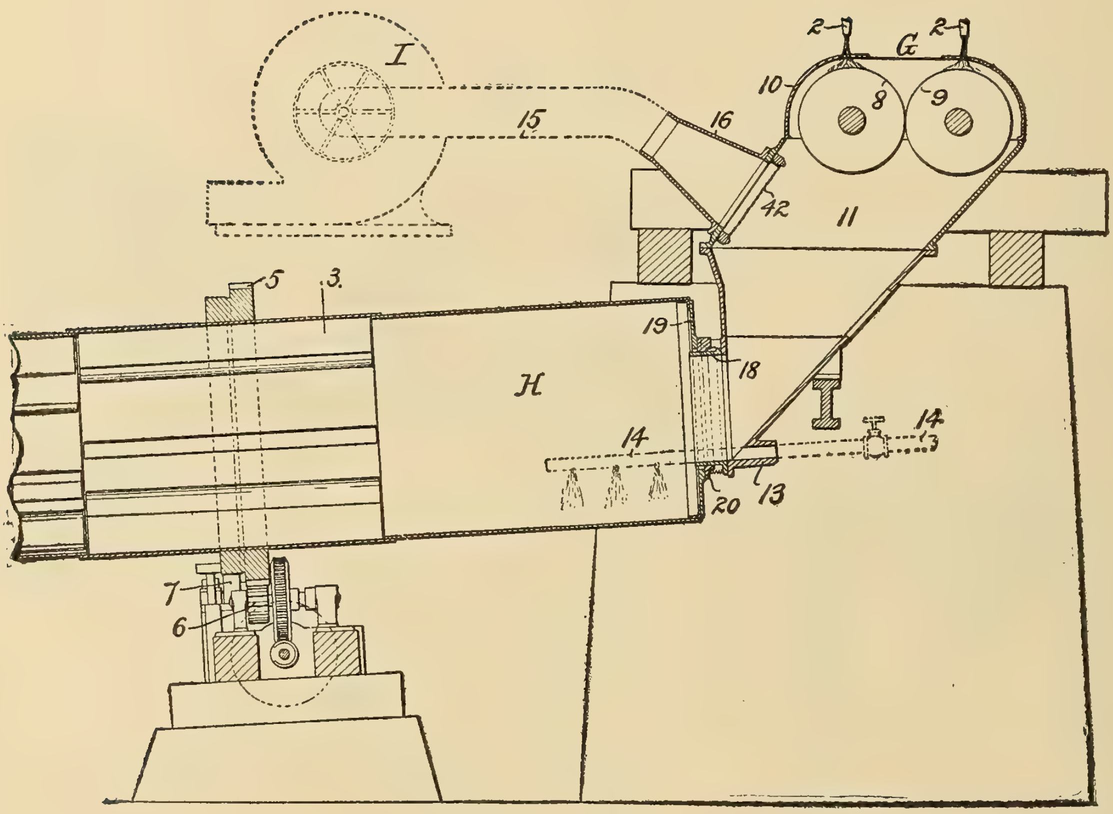
Plate 17 To face p. 711



Section of American rotary cylinder kiln for burning Portland cement (Mineral industry, 6:107)

Plate 18

To face p. 711



Detail of cooling chamber of rotary kiln (Mineral industry, 6:109)

Rotary kiln. This consists of an inclined revolving iron cylinder lined with fire brick (pl. 17). The slurry or dried mixture is charged at the upper end, and oil or gas fuel blown in at the lower, the gases of combustion passing through the chamber and out at the upper end, while the cement mixture slowly passes down through it, the burned clinker being discharged at the lower end.

At the present time the rotary kiln is gaining favor in the United States. It is claimed by Lewis[1] that the cost of oil fuel in this type of kiln is 28 to 40c a barrel, depending on the price of oil, but, using powdered coal, the fuel cost is greatly reduced.

There has also been a great improvement in the mechanical features of the kiln.

In this country the rotary kiln was first experimented with in 1889, when the Atlas cement co. of New York began to experiment at Coplay (Pa.) with revolving continuous kilns, employing crude petroleum for fuel. The oil was blown in by jets at one end and the products of combustion passed into a stack at the upper end of the inclined revolving cylinder. This kiln has been patented in England by Frederick Ransome, who also secured an American patent for it. Since 1889 its success has increased in America, and, though this type of kiln is said to have been unsuccessful in England, in this country there are no less than 40 of them in operation, both on the hard raw material of the Lehigh valley and on the soft, wet marls of Ohio and Michigan, and also limestones of New York. The revolving continuous kiln is perhaps therefore an American device, since its only successful development has been in this country. Originally employed with producer-gas, it was subsequently modified so as to use jets of crude petroleum, while latterly experiments have been made with a view to utilizing pulverized coal as fuel, and several plants are working kilns employing this fuel.

Certain improvements in the way of auxiliary cylinders for regenerating the heat in hot clinker have been perfected, and the Atlas cement co. has also worked out a scheme for sprinkling and cooling the clinker in a third cylinder, so that, when discharged from this, it will be ready for immediate grinding in the mill (pl. 18).

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[1] Min. ind. 7: 113.

Hoffman ring kiln. This is used at a number of works in Germany but thus far has not been introduced into the United States. It is circular in form and consists of a number of chambers which are connected by flues with a central stack, and also with each other. The fuel is charged through the top and the kiln is down-draft in its action. The fire is started in the first chamber, and the heat from that is used to heat up several of the subsequent ones before it passes off to the stack. The material is dried preferably in the shape of bricks.

The advantages are: saving in fuel of 10% to 20%; combustion more perfect than in dome kiln; kiln well under control; burning can be watched. The disadvantages are: not economical unless run continuously; material of chamber lining should be as basic as possible to avoid union with silica of cement.

There are about five different types of kilns in use in the United States at the present time, requiring three different methods of preparation for the raw materials, regardless of differences of preparation which may be required by the character of these materials. The following list quoted from Lewis may serve as partial illustration of this point.

MANUFACTORY	KILN	Approximate output a day No.	Barrels
Coplay cement co.	Schöfer continuous	9	55
Coplay cement co.	Ordinary intermittent	23	30
American cement co., Egypt	"	56	30
American cement co., Jordan	"	6	30
Atlas cement co.	Revolving continuous	20	150
Alpha cement co.	"	8	150
Vulcanite co.	"	3	150
Sandusky co.	"	4	120
Bronson co.	"	3	120
Empire co.	Ordinary intermittent	18	130
Glens Falls co.	Schöfer continuous	8	60
Whitecliffs Ark.	"	8	60
Buckeye cement co.	Ordinary intermittent	..	30

MANUFACTORY	KILN	Approximate output a day No.	Barrels
Buckeye cement co...........	Dietzsch continuous..	...	50
Diamond cement co........	[1] continuous	..	...
Yankton S. D..............	Johnson intermittent..	6	...
Bonneville cement co.......	Revolving continuous	3	150

A new plant near Egypt (Pa.) and another near Sandusky (O.) are both installing revolving continuous kilns, as is also one at Catskill (N. Y.)

Grinding the clinker. American practice uses a combination which has brought this step in the manufacture of Portland[1] cement to a high degree of perfection. The machinery used is in part of American manufacture and partly of foreign origin.

It has been found that the best results are obtained by using a gradual reduction of the clinker instead of attempting to grind it all fine at once, and, with this object in view, it is common to break the material up first into lumps by means of crushers of the Gates or Blake type and then pulverize it in ball or tube mills or mills of the Griffin type. Ball mills are sometimes used for the first grinding but in that case in conjunction with Danish tube mills.

The absence of separators is sometimes commented on, it being claimed that, if the sufficiently fine material were removed after each grinding, the capacity of the machines would be increased. Wind separators are occasionally used abroad, but find very little application in American practice. The following table, taken from the *Mineral industry*, v. 6, gives the fineness of different brands of native and foreign cements.

	Per cent passing sieves No. 50	No. 100	No 200
Saylors	100	96.4	....
Giant...........................	99	94.9	....
Atlas	99.5	92.7	....
Alpha	99.7	94.8	....

[1] Rebuilding.

	Per cent passing sieves No. 50	No. 100	No. 200
Vulcanite	99.6	95.3	....
Sandusky	99.6	92.8	....
Brooks, Shoobridge & Co	98.8	88.3	....
Aslen	99.7	92.4	68.4
Aalborg	100	99.6	72
Condor	99.6	88.5	....

Ball mills. At many factories a ball mill is used, which consists of a revolving cylindric chamber, divided into segments with inclined steps. In this chamber is placed the clinker together with a number of flint balls, and, owing to the rotating action, the clinker is pulverized. The surface on which the balls travel is of hard metal. It is also perforated so that, as soon as the clinker is ground fine enough, it falls through on a metal screen, which retains the coarser grit, the finer particles passing on through gauze. Pl. 19, 20 show a sectional view of a ball mill.

Tube mills (pl. 21). These are also used for the reduction of the clinker, and consist of an iron cylinder about 15 feet long and 4 feet in diameter, half filled with flint balls. The chief object of the tube mill is to complete the grinding of the cement, the preliminary grinding of the clinker taking place in some other machine.

The cylinder rotates at a speed of 25–30 revolutions a minute, and the material, which is charged at one end, gradually works its way out to the other, though the mill is horizontal. The lining of the mill is either of cast iron strips or specially prepared brick. The material fed to it should have been previously crushed to 20 mesh. If used in conjunction with millstones, they take the heaviest part of the wear off the latter. Their capacity depends of course on the fineness to which the material is to be ground. Butler[1] gives the following figures illustrating the capacity of these mills under given conditions.

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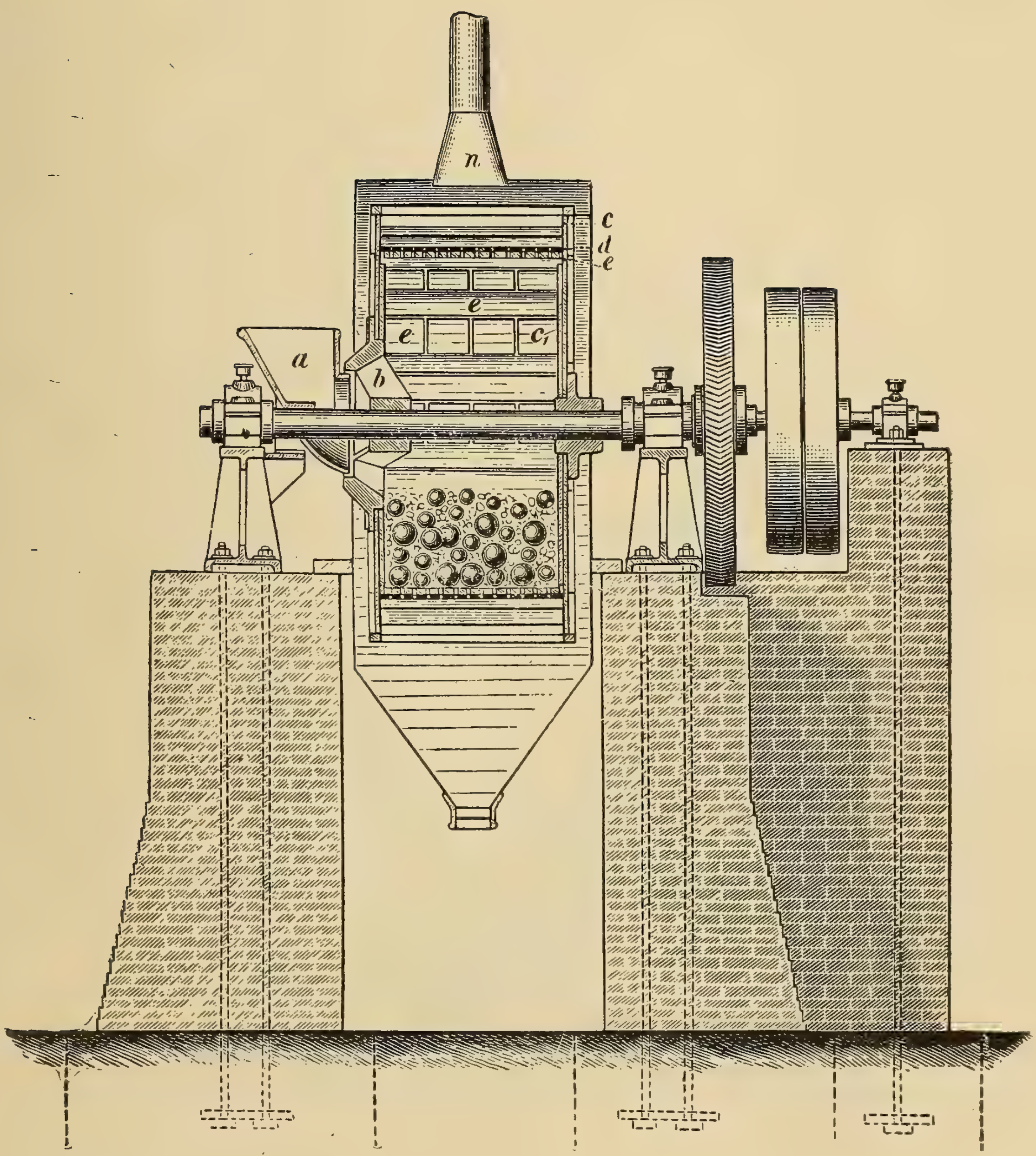
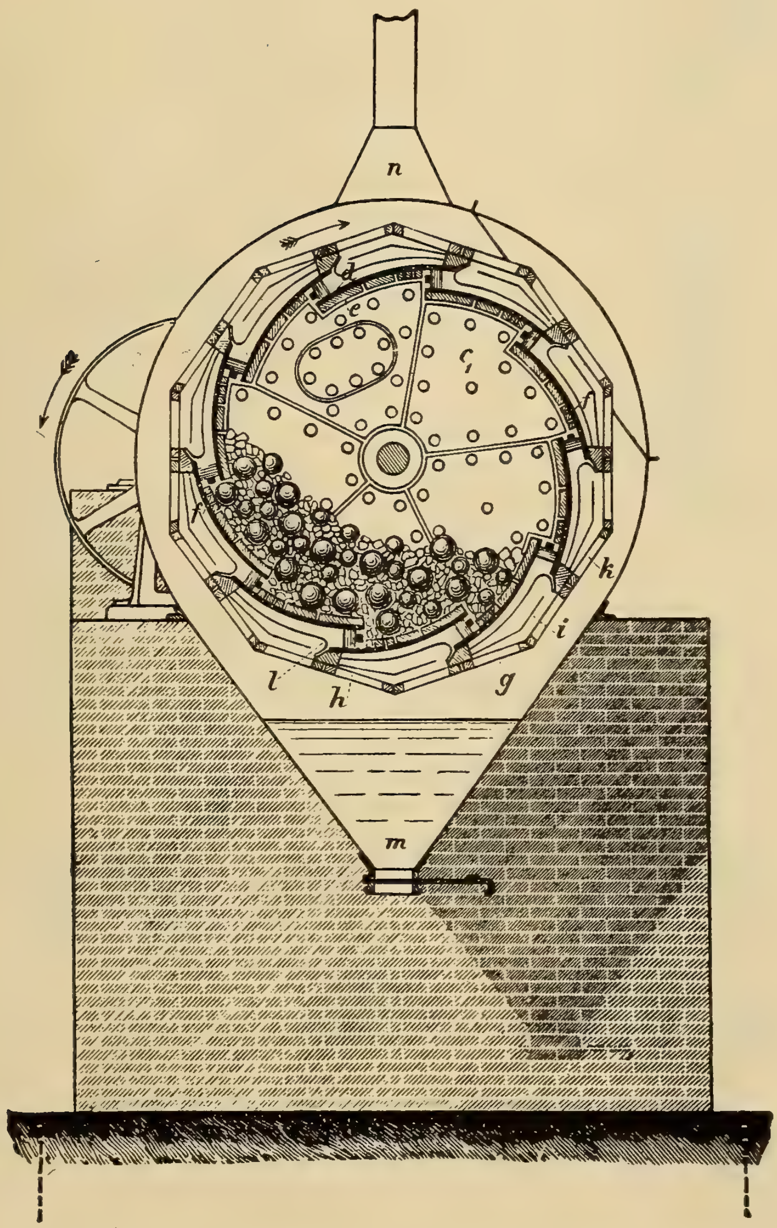
[1] Portland cement, p. 140.

To face p. 714



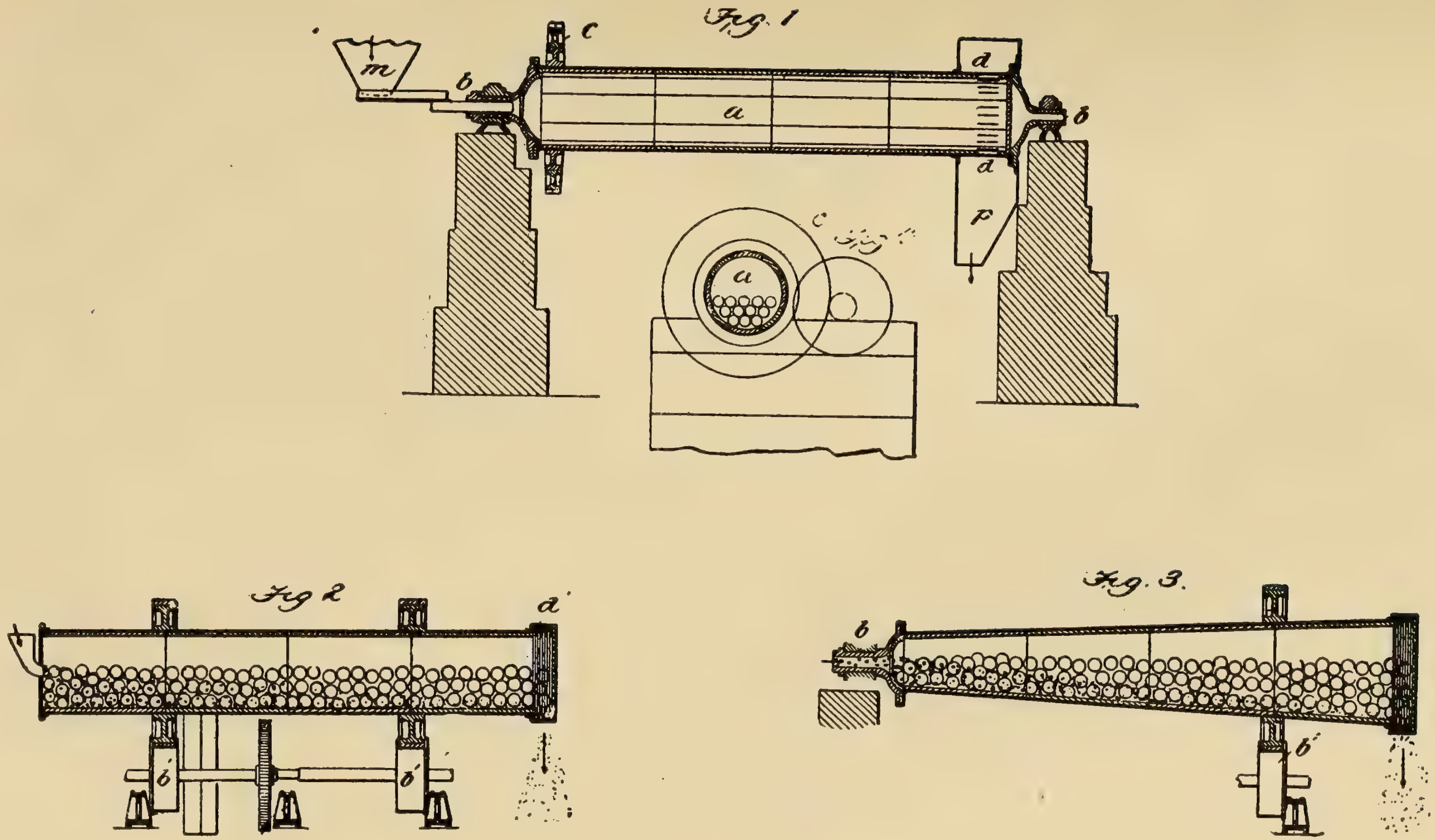
Section through shaft of ball mill used for grinding cement clinker (F. L. Smidth & Co.) *c* endplates; *d* drumplates; *e* steel plates for protecting drumplates.



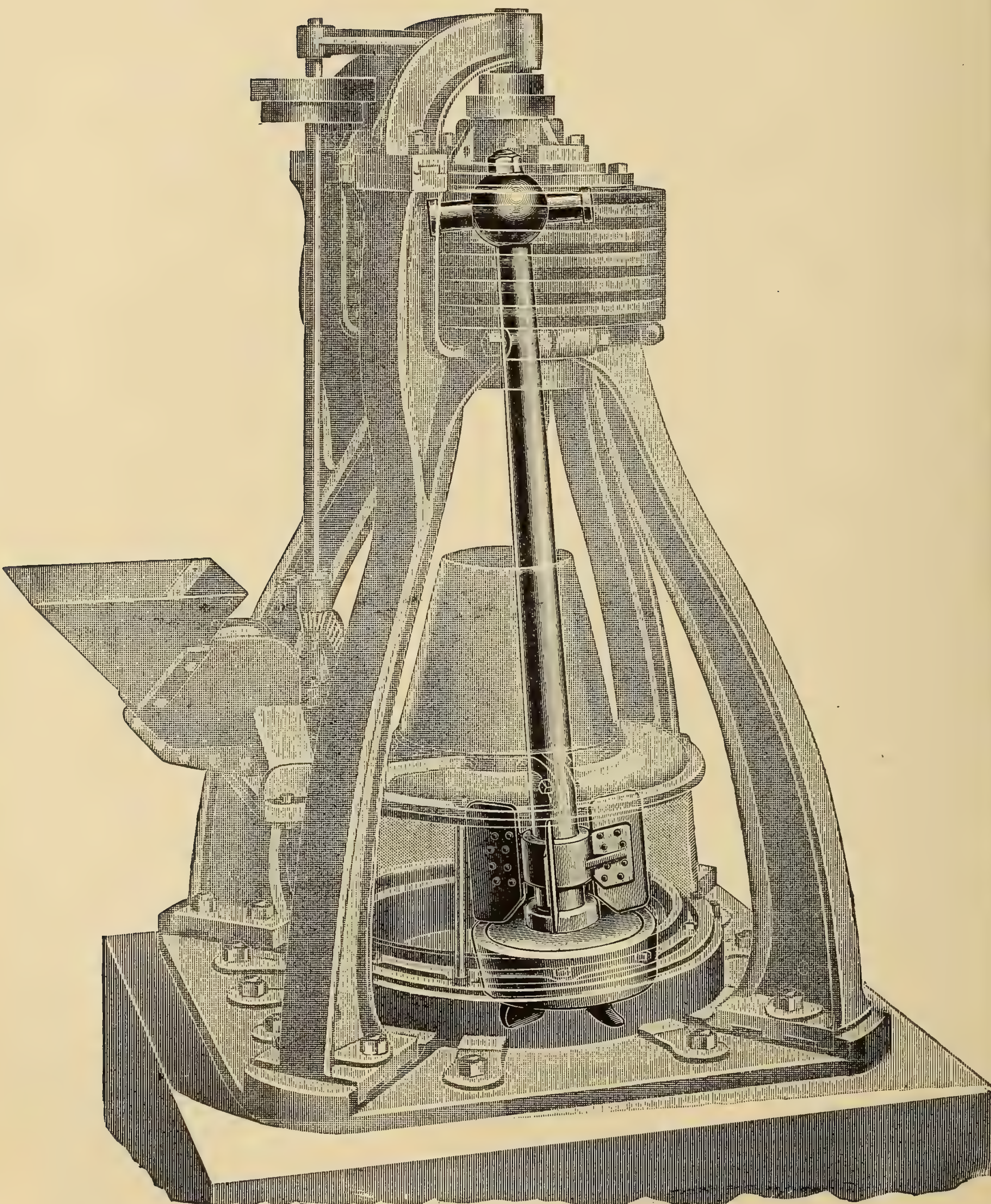
Section through ball mill showing grinding plate and sieve arrangement (F. L. Smidth & Co.) *f* perforations in grinding plates through which crushed material falls on screen plates; *g*, *i* inner sieves; *k* finishing sieves, the screenings from which are caught in hopper *m*.

Plate 21

To face p. 714



Sections through Davidsen tube mill (F. L. Smidth & Co.)
a drum; *b* bearing pivots; *c* cogwheels for rotating drum; *d* discharge openings; *m* supply chute; *P* discharge chute



Griffin mill (Bradley pulverizer co.)

Residue to the linear inch of sieve-holes

	180 per cent	100 per cent	76 per cent	50 per cent	OUTPUT
1 Material entering mill........	47	38	34	28	$2\frac{1}{4}$ tons an hour
Material leaving................	23	12	6	1	
2 Material entering	72	67	62	56	$4\frac{1}{2}$ tons an hour
Material leaving...........	37	24	16	6	

At many works the ball mills and tube mills are used in connection with each other.

Griffin mill (pl. 22). The Griffin mill is used at some factories for grinding the finished product. It consists of a steel ring, against the inside surface of which a heavy steel roll revolving on a vertical shaft presses by centrifugal force. The mill is provided with screens, so that, as soon as the material has reached the required fineness, it can pass through, the coarser particles however dropping back into the mill. This type is much used in German and other continental works.

The Griffin mill is used chiefly for grinding those particles which have been rejected by the sieves, and often in conjunction with millstones. In many factories however it performs the entire work of reduction. The crushing roll is attached to a shaft suspended vertically from a ball joint. To the bottom of the roll there is attached a series of plows or stirrers, so that, when the pan below contains sufficient material to come in contact with the plows, it is thrown up between the crushing roll and the die.

Two sizes of this machine are made, the diameter of the ring or die of the smaller being 30 inches and of the larger 36 inches, the diameters of the respective rolls being 18 and 22 inches. The pulley speed for each machine is 200 and 150 revolutions a minute.

Butler states that, at one mill where two of these machines are

in use, of 30 and 36 inches respectively, the larger mill is worked on tailing from the separators only, the hourly output being 38–40 cwt when ground to about 2% on 50. The smaller sized mill is worked on tailings from the separators and clinker from the crusher mixed, a rough grating being placed in the clinker hopper to prevent any pieces larger than a walnut from going forward into the mill, as such pieces would choke the worm feed. The smaller mill under these conditions is said to yield 26–30 cwt an hour.

Mills compared. H. Faija makes the following comparisons.

The power consumed by the several principles, reduced to the proportions of 1 ton of cement an hour, may be approximately stated as follows: for millstones 30–32 horse power per ton an hour; ball principle 16–18; edge runner principle 12–14. In each case the cement is ground to a fineness of a 5% residue on a 50 x 50 sieve, and it will thus be seen that the power required is proportionate to the amount of flour produced.

Butler declares, from microscopic analysis of different cements, that the statement that millstones produce an angular grain, and edge runners a rounded one, is incorrect.

Testing

There are as yet no universally accepted standard methods of testing, but the characters which may be, and often are determined are: compressive strength; tensile strength; rate of setting; boiling test; abrasion; permanency of volume; degree of fineness; adhesion; specific gravity.

Mixing the mortar

In 1885 the American society of civil engineers suggested testing briquets of neat cement, and, in addition, briquets of cement and sand: those of natural cement with one part sand, and those of Portland cement with three parts sand by weight. Some authorities advocate the abandonment of the neat cement test, since in use the material is always mixed with sand. The ratio of

sand to cement is commonly 3 to 1 in case of Portland and two to one in case of natural rock cement.

Johnson states:

> For special purposes 4 to 5 parts of sand may also be employed, specially with finely ground cements, such as give a residue of less than 10% and a sieve with 14,400 meshes per square inch. Since in the sand mixtures a standard sand must be employed, it has become necessary to use clean sharp sand which has passed a no. 20 sieve and stopped on no. 30.

In order farther to insure the identity of the sand, the American society of civil engineers has recommended that crushed quartz be used, such as is used in the manufacture of sandpaper. Johnson does not favor this practice; for the material has fully 50% of voids, while the ordinary sands with roughly rounded grains have but 33% of voids. Any good sharp sand therefore of the size, 20–30, should give very nearly uniform results, which will average much higher than those obtained with crushed quartz, unless the quartz briquets be thoroughly compacted by hard hammering.

The amount of water added will vary somewhat with the kind of cement, but it should be very little, in fact just enough to produce a mixture resembling damp sand. Jameson gives the approximate amounts (p. 55) as 20% to 25% for neat cement, 15% for one part sand, and 10% to 12% for three parts sand. It is always well to note the amount of water used. The temperature of the water and also of the laboratory should be between 60° and 70° F.

The mixing should always be done on a non-absorbent surface, and the sand and cement should be mixed dry, and then the water added.

Compressive strength

The test for compressive strength is seldom carried out, the reason being that the results are apt to be uncertain even though care be taken in the preparation of the specimens. They must

be all exactly of the same size, and have the sides exactly parallel and the ends exactly perpendicular to them. This is only obtainable when large cubes are used, and these require great machines to crush them.

M. Gary states[1] that in order to obtain agreement between different compression tests, the specimens should be made by machinery, and gives the following directions.

Take 400 grams (14 ounces) of cement and 1200 grams (42.2 ounces) of dry standard sand, mix thoroughly in a dish, add 160 grams (3.6 ounces) of water, and work the resulting mortar thoroughly for five minutes (quicksetting cements are to be worked but one minute). Put 860 grams (30.3 ounces) of this mortar into the cubic mold properly provided with filling cases and fastened to the bed plate. The iron core is placed into the form, and 150 blows are delivered on it by means of the hammer apparatus, with the hammer of 2 kilograms (4½ pounds) weight. The filling cases and core having been removed, the specimen is struck off flush, smoothed and drawn off the bed plate together with the mold.

For neat cement specimens, mix about 1000 grams (2.2 pounds) cement with the requisite amount of water. The molds should be oiled a little, and can be removed only after the cement has sufficiently hardened, which is usually from 20 to 24 hours after making.

While the elasticity of Portland cement decreases after some years, and the tensile strength ceases to grow after a similar period, its compressive resistance increases.

The machines used for determining the compressive strength are similar to those employed for the crushing of building stones and bricks. The compression test is seldom carried out in the United States.

Tensile strength

To carry out this test the cement is mixed with water to the consistency of a stiff paste and formed into briquets, this being done by means of brass molds.

When the cement alone is used it is spoken of as "neat" cement. When mixed with sand the term "cement mortar" is

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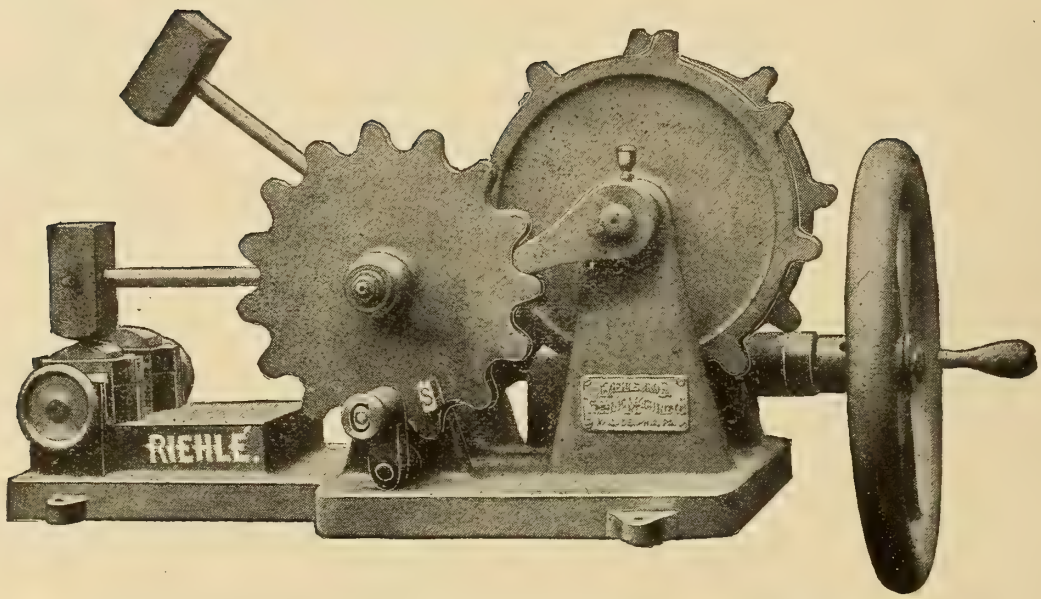
[1] Trans. Am. soc. civ. eng. 30: 25.

Plate 23 To face p. 719



Böhme hammer, used for making cement briquets (Riehle Bros.)

applied to it. The briquets are allowed to "set" either in air or water and are then pulled apart after a time, the number of pounds a square inch required to do this being recorded. This is the usual test made on cement, and, while it is not subjected to a tensile strain in actual work, still it gives a good idea of the strength of the cement, and is easily carried out. The briquets should be made of cement taken freshly from the barrel.

Form of briquets. Several different forms of briquets have been devised, but all have been so designed as to cause the briquet to break at its minimum cross-section. The American society of civil engineers recommended a standard size of briquet, which is one inch thick and the same in width and weakest in the center. This is smaller than that which is made in England or on the continent, but it gives satisfactory results, and the smaller size makes it less likely to have air bubbles.

Briquets may be made either by hand or by machine. When made by hand, the mortar is mixed with a trowel and pressed into the mold with it also. It is always desirable for the same person to make all of one series of briquets. It is claimed that, when the material is pressed into the mold with the trowel, the pressure exerted on the briquet is not evenly distributed over the surface. The briquet molds are usually constructed of brass, and are made in two pieces.

Molding briquets. There will always be some variation in the tensile strength of briquets. Jameson claims that, with the use of his briquet-molding machine, the variation was reduced to about 4%[1]; and the Böhme hammer (pl. 23) is said to accomplish the same object.

Heath in his *Manual of lime and cement*, p. 83, gives the following method for insuring uniformity in the briquets:

"The mixed cement is to be lightly placed in the molds, and is then to be pressed for five minutes under a load of 10 pounds

[1] Jameson. Portland cement, p. 54.

placed on top of the soft cement projecting above the mold." The loading block is shaped to the mold with $\frac{1}{64}$ of an inch clearance and is to be placed on the cement symmetrically; after loading, the surplus cement is to be cut off with a trowel or a knife, and the briquet smoothed level with the top of the mold. "With the exercise of the greatest care, the handmade briquets do not compare with those made with the machine."

Another advantage of machines is the rapidity with which the briquets can be made, and an additional advantage of this is that a lot of material can be mixed up at once.

In making briquets by hand enough material is usually mixed to make four or five briquets at once, and this is necessary if the material is at all quick setting.

All tensile test briquets should be kept in a moist atmosphere for 24 hours, and then kept the remainder of the period in water. It is important that the water used in mixing and also the bath in which the briquets are immersed should be kept at a constant temperature, so that uniform results may be obtained. Thus it has been found that in Portland cement the time of setting is shortened by increasing the temperature of the mixing water, while the strength attained in a given time may be greatly increased by raising the temperature of the bath from 40° to 80°[1]. In case of normal mortar, 1C: 3S, this increase at two months was from 100 to 230 pounds per square inch.

Briquet machines. The object of these is to bring about uniformity of pressure in the molding of the briquets. A number of such machines have been devised but comparatively few of them are in use. The Böhme hammer is a machine much used in Germany for this purpose (pl. 23). According to M. Gary[2] it consists of a tilt hammer with automatic action. The hammer is driven by a cam wheel of 10 cams actuated by simple gearing, and the wrought iron handle of the hammer is let into the crosshead

2 Johnson. Materials of construction, p. 408.
Trans. Am. soc. civ. eng. 30: 24.

which carries the axle of the hammer, and keyed to this crosshead and to the cap, so that it may be readily replaced if worn. The steel hammer, weighing $4\frac{1}{2}$ pounds, is similarly fastened to the cap. As soon as the intended number of blows has been delivered, the mechanism is automatically checked, the machine having been so adjusted before the beginning of the work.

The number of blows required in the standard German tests is 150. The forms to receive the mortar consist of a lower and upper case held together by springs. The lower case for compression specimens consists of two angle irons held on a plane plate by a grinding strip and a screw acting on the latter. Upward motion is prevented by two wedge-shaped surfaces. The lower case and half the upper ones are filled with the mortar to be tested, and a plate laid on its surface. On this plate the blows are delivered. It is of vital importance that the apparatus should rest on a firm non-elastic base.

The Jameson machine[1] is described by the author as follows:

The main portion of the machine consists of a cylinder, which is flanged at the lower end, this flange corresponding in size and shape to the upper part of the base. The cylinder is bolted to the base by four bolts, each bolt provided with a filler that holds the lower face of the filler 1 inch above the base plate. Both of these faces are accurately planed. It is between the two plane faces that the molding plate swings, the fillers on the bolts acting as stops. The bore in the cylinder is the shape and size of the briquet. In the bore there works a solid plunger, and the length is sufficient to cover the feed hole when at its lowest points. This plunger is operated by a lever. At either side of the plate are two extractors which correspond in outline and size to the opening in the plate, and which are raised by means of levers thus forcing the molded briquet from the plate.

A high capacity is claimed for this machine, it being stated that three students have made 3000 briquets in 10 hours.

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[1] Jameson. Portland cement, p. 50.

Cement-testing machines. A number of different machines have been devised. The two generally used in this country are Fairbanks's and Riehle's.

In the Riehle machine (pl. 24) the strain is applied to the specimen by means of a screw attached to the lower clip. The upper clip is attached to a graduated steel bar on which there slides a weight. This bar is kept balanced during the test by moving the weight along it with the aid of the upper wheel. Both wheels must be operated at the same time, and the end of the upper beam or indicator kept as nearly as possible in the middle of the opening in which it moves. The amount of strain on the specimen is shown by the position of the sliding weight.

The Fairbanks machine is of more compact form, and its construction is best understood by reference to the figure. After putting the briquet into the clips the levers are balanced, and the hopper filled with shot. This is allowed to run out into the bucket till the briquet breaks, when the stream of shot is stopped automatically (pl. 25).

Clips. Several forms of clips are made. The early ones had rather sharp edges which came in direct contact with the briquet; but this has been found objectionable, partly from the fact that the briquets were not always of just the right form to insure a perfect bearing. The result of this was that a false strain was often brought on the briquet, causing it to break at a lower point than it really should, and also at some other point than its minimum section. This trouble has been overcome in a measure by introducing cushions between the metal and the briquet, or even supplying the edges of the briquet with rubber rolls.

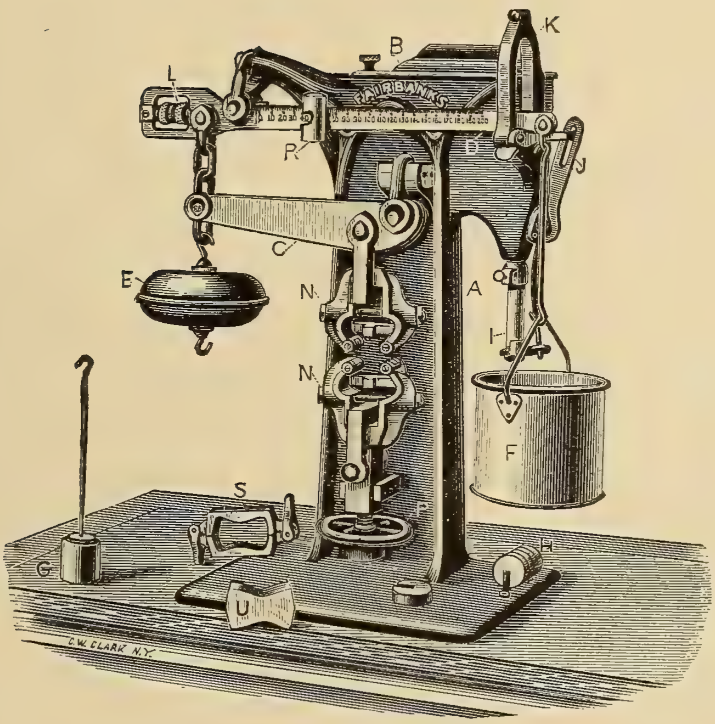
Johnson gives the essential features of the clips as follows.

1 They must grasp the briquet by a hard cushion bearing on four symmetric flat surfaces.

2 They must be freely suspended from a pivot bearing, so as to turn without friction while under stress.

Riehle Bros. machine for testing cement briquets

Plate 25 To face p. 722



Fairbanks machine for testing the tensile strength of cement briquets
N clips for holding briquets; P screw for applying strain to balance lever C; F bucket to hold shot, fed in through I, from the hopper K; J automatic cut off

3 They must be so rigid that they will not spread appreciably when subjected to their maximum load.

Placing briquet in machine. This should be carefully done, seeing that not only is the briquet in straight, but also that it has a full bearing surface. The pressure should be applied slowly, not faster than 500 pounds a minute. A note should be made of the number of pounds required to break the briquet and also of the character of the break. When the fracture is uneven, or does not occur at the minimum section, a note is always made of the fact, and the cause of this should be ascertained if possible.

Sand used. Two kinds of sand are used in cement tests, depending on the object for which the tests are being made. In the one case, when the cement is to be used in a particular piece of work, then it should be mixed with the sand that it will be mixed with in the actual work of construction.

If the cement is being tested simply for comparative purposes, or there is uncertainty as to the quality of the sand, then standard sand should be used. The standard is clean crushed quartz of such size that it will go through a no. 20 sieve, but be retained on a no. 30 sieve.

After molding and removal from the molds the briquets are set on non-absorbent slabs for 24 hours under a damp cloth, after which they are removed, half of them being put under water. The style of the tanks or pans used varies with the arrangement of the laboratory and the fancy of the person making such tests. The briquets when placed under water are always set on edge.

Temperature of briquets. In cements there may be a slight increase in temperature following the molding, which is due to the presence of free lime. In good Portland cements this rise in temperature is very slight, but is often sufficient to be felt by placing the hand on the briquet. In light burned natural cements there is often an appreciable rise in the temperature.

Setting of cement

By the setting of cement is meant the change that takes place from a soft mass to a hard brittle solid. This change, while varying in different cements, is on the whole a very rapid one at first, and then proceeds more slowly. It is always accompanied by the evolution of heat. The change which takes place is that in the burning of the cement an anhydrous silicate of aluminum and lime is formed which is soluble in water. On solution taking place the material at once changes to a hydrate which is insoluble and consequently crystallizes out, this crystallizing action causing the hardening.

A number of different ideas are held on this point, and the problem is a very complex one, which has as yet been only partially solved. Fremy considers that the formation of an aluminate of lime is responsible for the hardening property, and he also considers that the silica and alumina of the clay are separated by calcining and take on allotropic forms ready to unite into new compounds with the quicklime when the water is added. The work of S. B. Newberry in this line is of the highest importance, and has already been referred to (p. 697–99).

The set of the cement is determined by what is known as the needle test. Gen. Gilmore was one of the first to use this test in this country. It consists in determination of the penetration of a needle of wire of known cross-section and of given weight. The needle used by Gilmore as described by him was slightly conical, tapering toward the point, and truncated at right angles to the axis so as to give a diameter at the lower end of $\frac{1}{12}$ of an inch. It protrudes from a socket at the lower end of a spindle or vertical rod, to which it is firmly secured by means of a thumbscrew. To the upper extremity of the spindle is attached a diagonal scale of steel, accurately graduated to tenths, hundredths, and thousandths, of an inch, and provided with a horizontal index firmly fixed to the framework of the instrument. The absolute penetration of the needle is obtained by taking the

difference of the readings on the index before and after the impact. The falling body is a hollow metal cylinder, weighing 1 pound, of which the exterior diameter is about equal to the length. This cylinder in its descent passes freely over the spindle and strikes on the shoulder attached just above the screw.

Another device used by Gen. Gilmore was a $\frac{1}{12}$ inch wire with a flat end, and loaded with $\frac{1}{4}$ of a pound, and a $\frac{1}{24}$ inch wire also loaded with 1 pound. These were used on cakes of neat cement, 2 or 3 inches in diameter, $\frac{1}{2}$ inch thick at the center, and $\frac{1}{4}$ at the edges. One cake was left in the air and one in the water. The time at which the loaded wire ceased to penetrate the pat was noted.

In England those Portland cements are called quick setting which will bear the $\frac{1}{12}$ inch needle loaded with 4 ounces in 10 minutes after mixing with water, and to be slow setting if they require 30 minutes or more, up to 5 hours. If they will not bear the weight of the needle after this period, the cement is rejected.

Still another test is that with Vicat's needle. The needle has a cross-section of 1 millimeter and bears a weight of $10\frac{1}{2}$ ounces. The depth to which the needle penetrates the cement is read off on a scale.

A quick setting cement may begin within a few minutes after wetting, while a slow setting one may not begin till 24 hours after it has been wet, though, when once begun, the setting usually goes on rapidly.

Setting is always accompanied by a slight rise in temperature, which continues while the setting is going on. The rise in temperature is less in slow setting cements. As the setting of cement is also influenced by the temperature of the air and water, it is recommended by Gary that, in order to obtain comparable results, the tests should be made at a mean temperature of 15° to 18° C.[1]

[1] Trans. Am. soc. civ. eng. 30 : 11.

Portland cement becomes slow setting through long storage, though at first it may gain in its setting speed if kept in a dry place free from drafts.

Jameson also states that some cement, when taken from the mill and gaged with water, is found to be moderately slow setting, but after 24 to 30 hours will set almost before it can be mixed. Store it in a cool, dry place and in a few days it will become slow setting.

The speed of setting usually decreases with the age of the cement, provided it has been stored in a dry place. Some consider that slow setting is due to free lime, but other factors also enter into the problem, such as the underburning or overburning of the cement, the underburned setting quicker. A vitrified cement will never set.

Boiling test

This is the one that has been recommended as the best for determining the soundness of a cement. At the fifth international convention for unifying methods for testing construction materials, held in Zurich in September 1895, the rules for conducting this test were laid down as follows.

1 The rapidity test of hydraulic cements for constancy of volume consists in the application of warm baths at temperatures of from 50° to 100° C.

2 Manner of making test pieces. Enough water is used to bring the neat cement after proper working into a plastic state. Two balls from 1.5–2 inches diameter are formed by hand and kept in moist air resting on some non-absorbent material. (Sand mixtures are not subjected to this test, neither are briquets that are to be tested for tensile strength.) The employment of tension briquets and cylindric disks from 2 to 4 inches in diameter, from ¾ to 1¼ inches thick, is likewise permitted.

3 Duration of previous hardening. Till set has taken place, test pieces must be kept in moist air. Portland, slag, pozzuolana, and Roman cement will be kept uniformly thus for 24 hours,

very slow setting cements for 48 hours. Hydraulic limes and all cements that have not set after 48 hours will be allowed 72 hours for previous hardening.

4 Treatment in the water bath. The previously hardened test samples are placed in a water bath at the ordinary temperature, which is then gradually — in not less than 30 minutes — heated to the prescribed temperature and kept there. After three hours at this temperature the test is interrupted, the test pieces are taken out of the bath, and, after having cooled sufficiently, examined as to their condition. They must not be chilled suddenly by means of cold water.

For each warm bath test the water must be renewed. The temperature of the bath will be: for Roman cements and hydraulic limes, 50° C. Portland, slag and pozzuolana cements, 100° C.

5 In order to be considered of absolutely constant volume, the sample must, during the test, remain perfectly sound and entirely free from cracks and warping. If the ball cracks slightly in this test or disintegrates somewhat, it should be considered at least as doubtful, though it might not fail in actual practice.

This test is not good for natural cements, as they will not stand it in most cases.

Abrasion test

This is sometimes applied to neat cement and also to mixtures of cement and sand when they are to be used for flooring. It depends on hardness of cement itself and also on its cementing qualities.

Jameson states that the grinding machines are of two kinds. A Berlin form is a cast iron disk that rotates 22 times a minute. The cube after seven days' immersion and drying is held on the disk with a clamp weighted to 56 pounds. 308 grains of Napus quartz is put on the plate at the start and at the end of the 15th revolution. After 30 revolutions the cube is weighed and the loss noted. Jameson uses a cube 3 inches on edge, and a coarse

emery wheel 4 inches in width and 15 inches diameter. The wheel is set vertically and given 100 revolutions a minute. The cube was loaded with a weight of 10 pounds at the end of a lever 3 feet long, and subjected to 200 revolutions.

The following figures given by Gary[1] show the loss by abrasion which some cements suffer.

Loss of weight by abrasion

No.	Length of tests	HARDNESS IN AIR					HARDNESS UNDER WATER				
		neat cement	1 cement 1 sand	1 cement 2 sand	1 cement 3 sand	1 cement 4 sand	neat cement	1 cement 1 sand	1 cement 2 sand	1 cement 3 sand	1 cement 4 sand
1...	7 days..	5.5	4.2	3.5	6.1	8.9	5	3.7	3.8	7.9	10.4
	28 ..	7.9	4.5	1.9	9.7	13.8	2.9	1.8	2.7	4.1	6.8
2...	7 ..	4.6	2.5	3.4	8.3	9.5	4.6	1.7	3	6.5	8.8
	28 ..	3.9	2	3.5	6	7.3	3.6	1.8	2.3	5	5.6
3...	7 ..	5.4	2.9	6.1	18.3	62.8	2.4	2.1	2.1	4.7	15.9
	28 ..	2.4	1.6	1.9	2.3	22.9	2.2	1.3	1.4	1.8	2.2
4...	7 ..	10.4	3.9	3.9	7.3	17.3	4	2.6	2.5	3.6	4.6
	28 ..	9	4	3.4	5.2	14.9	3.6	2.8	2.1	2.1	1.8
5...	7 ..	10.6	7.6	10.2	19.2	28.7	7	5.9	7.1	15.7	17.4
	28 ..	5.3	1.6	1.6	9	11.6	5.8	.9	1.1	2.3	13.4
6...	7 ..	6.2	2.3	4.2	6.5	17.1	3.5	1.3	2.2	5	10.9
	28 ..	5.3	2.2	3.3	4.4	8.9	3.9	1.3	2.2	2.7	3.9

No 1 a Holstein brand of cement; 2, 3, 6 Silesian cement; 4, 5 pozzuolana cement.

All of these cements are said to fulfil the Prussian regulations. They have a tensile strength after 28 days, when mixed 1–3, of over 230 pounds per square inch, and a compressive strength of more than 2300 pounds per square inch. A sieve of 900 meshes rejects less than 10%. They are of constant volume.

The specimens were tested by pressing them with a load of 56 pounds against a cast iron disk, rotating at the rate of about 22 revolutions a minute. 20 grams of Napus quartz, no. 3, were put on plate at start, and a similar quantity at the end of every 15th turn.

The body is weighed when starting and again at the end of the 30th revolution.

[1] Trans. Am. soc. civ. eng. 30: 40.

Adhesion

This test is usually applied by taking two pieces of glass 4 x 8 inches and 1 or 1½ inches thick. Mix the mortar and place it between them, with the slabs at right angles, and press the mortar out into a layer ¼ inch thick. The sample is allowed to stand 24 hours under a damp cloth, and then immersed in water. They are pulled apart at end of 7 or 28 days. Better results are often obtained by the use of brick and stone instead of glass.

Permanency of volume

Good cements should not expand or shrink appreciably in setting. If there has been any appreciable flaw in the manufacture of the cement, it will tend to expand or shrink, and disintegrate. This expansion is known as "blowing." One of the best methods of testing the constancy of volume of a cement is to mix it with a small quantity of water, and press it firmly into a straight glass lamp chimney. If any expansion takes place, it will crack the chimney. By the same means shrinkage can also be determined, this being done by putting some colored liquid in the chimney above the cement. If the latter shrinks, it will allow the liquid to run down the interior of the tube.

The expansion may take place immediately, or not show till several days after the cement has been mixed, depending on the rapidity of setting of the cement.

Another convenient means of testing for constancy of volume is to mix the cement with water, and make up a few ounces of it into a pat 3 inches in diameter, ¼ inch thick at the edge and ½ inch at the middle. Place this for 24 hours under a damp cloth and then in water. If it shows no cracks at the edges after three days, it will not be likely to blow.

Henry Faija, in the *I. civil engineers,* states that he uses the following method to hasten the test. He takes a vessel in which water can be maintained at a constant temperature of 110° or 115° F, and having a cover, under which and above the

water level is a rack on which the cement can be placed. The pat is made and then put on the rack for 6 to 8 hours, after which it is put in warm water from 16 to 18 hours. If at the end of that time it is firm and adheres to the glass, it can be considered safe. If it does disintegrate, it may simply indicate that the cement is too fresh. Cement is said to blow very often if tested 24 hours after making.

In making the pats it is necessary, specially in the case of slow setting cements, to protect them from the sunlight and drafts. For this reason they are covered with a moist cloth.

Gary claims[1] that, according to German experience, all tests to determine blowing with the exception of the German cake method are misleading, and that a swelling of cements (Portland) is really a rarity.

Cements of changeable volume, he maintains, differ in other properties, specially their tensile strength, from Portland cement, so that they are easily recognized. Some cements, however, such as highly magnesium ones, will, when burnt to a clinkered condition like Portland, refuse to swell when first mixed, and sometimes do not show an increase in volume when kept under water till nearly a year later, but they then show the property to a marked degree.

The apparatus used by the Germans for determining change in volume is known as Bauschinger's caliper apparatus, and can be made to show the change in volume that takes place in a specimen over an extended period of time (pl. 26).

It enables one to determine by direct measurement the changes in length of small parallelopipeds of about 100 mm (4 inches) long and 5 square cm (.78 square inch) area with an accuracy of $\frac{1}{200}$ mm ($\frac{1}{5000}$ of an inch). The apparatus consists principally of a stirrup-shaped caliper, having a fine micrometer screw on its right arm, the left being the support of a sensitive lever. The shorter arm of the lever terminates in a blunt caliper point, and is pressed against the measuring screw by a spring attached

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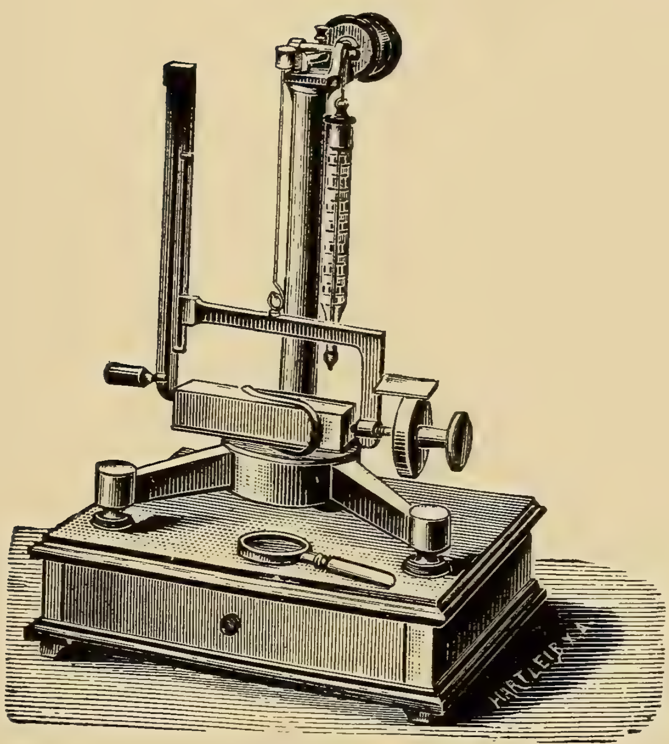
1 Trans. Am. soc. civ. eng. 30: 15.

Plate 26 To face p. 730



Apparatus for determining permanency of volume of Portland cement

to the long arm. The calipers are readily moved in any direction, and the micrometer is read in the usual manner. One revolution of the screw equals .5 mm ($\frac{1}{50}$ of an inch), and readings on the head are made at $\frac{1}{200}$ mm ($\frac{1}{5000}$ of an inch). The specimen is placed on a small platform, between the lever and the screw. The points of the calipers are set on center marks drilled into small glass plates let into the specimens.

The width between the caliper points is made equal to 95 mm ($3\frac{3}{4}$ inches) in each of these instruments, thus very much simplifying the computation for length. For instance, if the screw reads 9.56 revolutions, the absolute length of the specimens is $9.56 \div 2 + 95$ mm $= 99.78$ mm. The specimens are made in small metal frames, just as the standard specimens for tension. It is necessary, however, to turn the molds over repeatedly, and treat both the upper and under surfaces alike. If this is not done, and the upper surface becomes rather thick and smooth, which a repeated striking off with the trowel will accomplish, it may easily happen that the lower layers remain loose and porous, causing a distortion of the specimen, which may lead to considerable errors. The positions for the center-mark plates are provided for in the forms, and these plates may, therefore, be cemented into place as soon as the specimens are removed from the molds. To measure a specimen requires but a few minutes, the apparatus being very easy to manipulate.

In the following table, F and G are two cements which were tested for tensile strength in a 1–3 mortar, and showed but small strength. It will be noted that these two inferior brands showed an extraordinary degree of shrinkage, making them unfit for decorative purposes and laying of face stones. This extraordinary shrinkage explains the cracks shown on so many ornamental surfaces, artificial stones and plates, which always have either a neat cement or a mixture low in sand at their surface. The preference for a really good brand of cement for this purpose is thus explained. The table furthermore shows that the commonly adopted theory regarding a uniform relation between expansion when hardening under water and shrinkage when hardening in air is erroneous.

PORTLAND CEMENT BRAND	HARDENED IN AIR						HARDENED IN WATER					
	Neat cement			Normal mixture 1 to 3			Neat cement			Normal mixture 1 to 3		
	Time of hardening, in days											
	7	28	90	7	23	90	7	28	90	7	28	90
A Ground to ordinary fineness	—.555	—.121	—.134	—.019	—.034	—.086	+.021	+.037	+.048	+.006	+.012	+.033
A Not so finely ground	—.056	—.106	—.16	—.01	—.043	—.06	+.027	+.027	+.003	+.012	+.017	+.02
B	—.01	—.188	—.26	—.025	—.074	—.123	+.003	+.013	+.01	+.005	+.033	+.035
C	—.075	—.118	—.075	—.015	—.02	—.068	+.005	+.02	+.01	+.03	+.005	+.03
D	—.0 5	—.125	—.195	—.015	—.073	—.09	+.005	+.012	+.019	+.005	+.01	+.005
E	—.045	—.12	—.175	—.023	—.075	—.11	+.027	+.048	+.035	+.007	+.035	+.043
F	—.117	—.252	—.321	—.032	—.072	—.12	+.035	+.035	+.053	+.015	+.02	+.019
G	—.12	—.234	..	—.045	—.058	......	+.025	+.035	......	+.013	+.02	......

Fineness

As the quality of a cement is improved by grinding, it is common to test the degree of fineness. Fineness of grinding, while it improves the quality of the material, also increases the cost of manufacture, up to a point where the increase in cost is more rapid than the increase in quality; but grinding is seldom carried to this point.

The test is to pass it through a 100 mesh linear sieve, the residue remaining on the sieve and also the amount that passes through being noted.

Jameson states that a cement which will pass through a sieve of 625 meshes per square inch and only leave 4–5% residue on a 2500 mesh per square inch sieve is fine enough.

The degree of fineness is of great importance, for the setting is due to the chemical action that takes place between the finest particles of the cement. Johnson states[1] that "The proportion of the cement which passes a sieve of less than about 100 meshes to the linear inch does not give any intelligent idea of the significant fineness of the grinding. In fact, the standard sieve for determining the fineness now generally used on the continent of

[1] Materials of construction, p. 410.

Europe has 175 meshes per linear inch." 75% of the cement should pass through a sieve of this fineness.

Johnson recommends that a sieve of 120 meshes be used, and that not more than 20% of the cement shall remain on it. Most cements will pass through this.

Sand cement. If Portland cement has a certain amount of sand ground up with it to extreme fineness, it is found that as much sand can be mixed with it to form mortar as could have been added to the undiluted cement. This product is known as *sand cement*, and its manufacture was first begun in this country in 1895 by the Standard silica cement co. of Glens Falls (N. Y.) In Europe it was introduced some time before this, and is manufactured there quite extensively.

According to Newberry, " It is claimed by the manufacturers that the sand cement supplied by them gives only 5% residue on a 180 mesh sieve, and that 6000 barrels of this cement were used in the concrete foundations of St John's cathedral at New York. A description of the industry has been published in the *Engineering news*, Ap. 16, 1896, page 252. This paper gives the following comparative tests of sand cement 1–1, and Portland cement, each with three parts of ordinary sand.

	Pounds to 1 square inch		
	7 days	14 days	28 days
Sand cement 1–1, and 3 parts sand.....	156	188	200
Portland cement and 3 parts sand......	137	170	179

"An extensive series of tests has also been published by Wallin (*Thonindustrie zeitung*, 1896, p. 18) who concludes that the highest economy is obtained by grinding three parts of sand with one of cement." Mr Newberry says:

The good results given by sand cement are easily explainable, for it is wholly a question of filling up the voids in the sand. These voids in ordinary building sand amount to about one third of the total volume; therefore, if more than three volumes of sand be mixed with one of cement, the voids will not be wholly filled. By grinding a part of the sand to great fineness the pro-

portion of voids may be greatly reduced, and a mixture of one cement to six of sand may thus be made as effective as a one to three mixture with ordinary sand. It is evident that very many careful tests will have to be made to determine the precise proportions of cement and sand which will give a sand cement of the best efficiency. There can be little doubt however that the introduction of this new product will tend to increase the consumption of Portland cement, since it will make it possible to use Portland for common purposes at no greater cost than cheap hydraulic cement, and at the same time to obtain greatly superior results.

Specifications for Portland cement

In most countries where the Portland cement industry has assumed considerable importance, the engineering societies of those countries have adopted a series of specifications to govern the quality of Portland cement. The following abstracts of the American, German, and French specifications are quoted from Jameson.[1]

The testing of cement is not so simple a process as it is sometimes thought to be. No small degree of experience is necessary before one can manipulate the materials so as to obtain even approximately accurate results.

The first tests of inexperienced, though intelligent and careful, persons, are usually contradictory and inaccurate, and no amount of experience can eliminate the variations introduced by the personal equations of the most conscientious observers. Many things, apparently of minor importance, exert such a marked influence on the results that it is only by the greatest care in every particular, aided by experience and intelligence, that trustworthy tests can be made.

The test for tensile strength on a sectional area of 1 square inch is recommended, because, all things considered, it seems best for general use. For the small briquet there is less danger of air bubbles, the amount of material to be handled is smaller, and the machine for breaking may be lighter and less costly.

The tensile test, if properly made, is a good, though not a perfect indication of the value of a cement. The time requisite for making this test, whether applied to either the natural or the

1 Jameson. Portland cement, p. 68.

Portland cements, is considerable (at least seven days, if a reasonably reliable indication is to be obtained), and, as work is usually carried on, is frequently impracticable. For this reason, short time tests are allowable in cases of necessity, though the most that can be done in such testing is to determine if the brand of cement is of its average quality. It is believed, however, that if a neat cement stands one day tensile test, and the tests for checking and fineness, its safety for use will be sufficiently indicated in the case of a brand of good reputation; for, it being proved to be of average quality, it is fair to suppose that its subsequent condition will be what former experiments, to which it owes its reputation, indicate that it should be. It can not be said that a new and untried cement will by the same tests be proved to be satisfactory; only a series of tests for a considerable period, and with a full dose of sand, will show the full value of any cement; and it would be safer to use a trustworthy brand without applying any tests whatever than to accept a new article which had been tested only as neat cement and for but one day only.

The test for compressive strength is a very valuable one in point of fact, but the appliances for crushing are usually somewhat cumbersome and expensive, so much so that it seems undesirable that both tests should be embodied in a uniform method proposed for general adoption. Where great interests are at stake, however, and large contracts for cement depend on the decision of an engineer as to quality, both tests should be used if the requisite appliances for making them are within reach. After the tensile strength has been obtained, the ends of the broken briquets, reduced to one inch cubes by grinding and rubbing, should be used to obtain the compressive strength. The adhesive test, being in a large measure variable and uncertain and therefore untrustworthy, is not recommended.

The strength of a cement depends greatly upon the fineness to which it is ground, especially when mixed with a large dose of sand. It is, therefore, recommended that the tests be made with cement that has passed through a no. 100 sieve (10,000 meshes to the square inch) made of no. 40 wire, Stub's wire gage. The results thus obtained will indicate the grade which the cement can attain, under the condition that it is finely ground, but it does not show whether or not a given cement offered for sale shall be accepted and used. The determination of this question

requires that the tests should also be applied to the cement as found in the market. Its quality may be so high that it will stand the tests even if very coarse and granular, and, on the other hand, it may be so low that no amount of pulverization can redeem it. In other words, fineness is no sure indication of the value of the cement, although all cements are improved by fine grinding. Cement of the better grades is now usually ground so fine that only from 5% to 10% is rejected by a sieve of 2500 meshes per square inch, and it has been made so fine that only from 3% to 10% is rejected by a sieve of 32,000 meshes per square inch. The finer the cement, if otherwise good, the larger the dose of sand it will take, and the greater its value.

CHECKING OR CRACKING

The test for checking or cracking is an important one, and, though simple, should never be omitted. It is as follows: make two cakes of neat cement, 2 or 3 inches in diameter, about $\frac{1}{2}$ inch thick, with thin edges. Note the time in minutes that these cakes, when mixed with water to the consistency of a stiff plastic mortar, take to set hard enough to stand the wire test recommended by Gen. Gilmore, $\frac{1}{12}$ inch diameter wire loaded with $\frac{1}{4}$ of a pound, and $\frac{1}{24}$ inch loaded with 1 pound. One of these cakes, when hard enough, should be put in water and examined from day to day to see if it becomes contorted, or if cracks show themselves at the edges, such contortions or cracks indicating that the cement is unfit for use at that time. In some cases the tendency to crack, if caused by the presence of too much unslaked lime, will disappear with age. The remaining cake should be kept in the air and its color observed, which, for a good cement, should be uniform; the Portland cements being of a bluish gray throughout, yellowish blotches indicating poor quality; and the natural cements being light or dark, according to the character of the rock of which they are made. The color of the cements when left in the air indicates the quality much better than when they are put in water.

TESTS RECOMMENDED

It is recommended that tests for hydraulic cement be confined to methods for determining fineness, liability to checking or cracking, and tensile strength; and for the latter, for tests of seven days and upward, that a mixture of one part of cement to one part of sand for natural cements, and three parts of sand for

Portland cements, be used, in addition to trials of the neat cement. The qualities used in the mixture should be determined by weight.

The tests should be applied to the cements as offered for sale. If satisfactory results are obtained with a full dose of sand, the trials need go no further. If not, the coarser particles should first be excluded by using a no. 100 sieve in order to determine approximately, the grade the cement would take if ground fine; for fineness is always attainable, while inherent merit may not be.

The following table, showing the average minimum and maximum tensile strength per square inch which good cements have attained when tested under the conditions specified elsewhere in the report, has been prepared by the committee. Within the limits given in the following table the value of a cement varies closely with the tensile strength when tested with the full dose of sand.

American natural cement, neat:

One day; one hour, or until set, in air, the rest of the 24 hours in water, from 40 to 80 pounds.

One week; one day in air, six days in water, from 60 pounds to 100.

One month (28 days); one day in air, 27 days in water, from 100 pounds to 150 pounds.

One year; one day in air, the remainder in water, from 300 pounds to 400 pounds.

American and foreign Portland cements, neat:

One day; one hour, or until set, in air, the rest of the 24 hours in water, from 100 to 140 pounds.

One week; one day in air, six days in water, from 250 to 550 pounds.

One month (28 days); one day in air, 27 days in water, from 350 to 700 pounds.

One year; one day in air, the remainder in water, from 450 to 800.

American natural cements, one part of cement to one part of sand:

One week; one day in air, six days in water, from 30 pounds to 50.

One month (28 days); one day in air, 27 days in water, from 50 to 80 pounds.

One year; one day in air, the remainder in water, from 200 to 300.

American and foreign Portland cements, one part of cement to three parts of sand:

One week; one day in air, six days in water, from 80 to 125 pounds.

One month (28 days); one day in air, 27 days in water, from 100 to 200 pounds.

One year; one day in air, the remainder in water, from 200 pounds to 350 pounds.

Standards of minimum fineness and tensile strength for Portland cement, as given below, have been adopted in some foreign countries. In Germany, by Berlin society of architects, Society of manufacturers of bricks, lime and cement, Society of contractors, and Society of German cement-makers.

Standard of 1877. Fineness, not more than 25% to be left on sieve of 5806 meshes per square inch.

Tensile strength, 1 part cement, 3 parts sand, 1 day in air, 27 days in water, 113.78 pounds per square inch.

Standard of 1878. Fineness, not more than 20% to be left on the sieve, as above.

Tensile strength, same mixture and time as above, 142.23 pounds per square inch.

In Austria, by Austrian association of engineers and architects.

Standard of 1878. Fineness same as German of 1878.

Tensile strength, same mixture as above, 7 days, 1 day in air, six days in water, 113.78 pounds per square inch.

28 days, 1 day in air, 27 days in water, 170.68 pounds per square inch.

In Austria a standard for the minimum fineness and tensile strength of Roman cement was established and generally accepted, as follows.

Standard of 1878. Fineness, same as Portland.

Tensile strength (1 part of cement, 3 parts of sand) for:

Quick setting (taking 15 minutes or less to set):

Seven days, 1 day in air, six days in water, 23 pounds per square inch.

28 days, 1 day in air, 27 days in water, 56.9 pounds per square inch.

Slow setting cement (taking more than 15 minutes to set):

Seven days, one day in air, six days in water, 42.6 pounds per square inch.

28 days, one day in air, 27 days in water, 85.3 pounds per square inch.

The Roman cements correspond to those classified in this report under the head of natural cements.

Standards have been adopted also in Sweden and Russia.

MIXING, ETC.

The proportions of cement, sand and water should be carefully determined, by weight, the sand and cement mixed dry, and the water all added at once. The mixing must be rapid and thorough, and the mortar, which should be stiff and plastic, should be firmly pressed with a trowel, without ramming, and struck off level; the molds in each instance, while being charged and manipulated, to be laid directly on glass, slate, or some other non-absorbent material. The molding must be completed before incipient setting begins. As soon as the briquets are hard enough to bear it, they should be taken from the molds and kept covered with a damp cloth until they are immersed. For the sake of uniformity, the briquets, both of neat cement and those containing sand, should be immersed in water at the end of 24 hours, except in the case of the one day tests.

Ordinary, fresh, clean water, having a temperature between 60 and 70° F, should be used for water of mixture and immersion of samples.

The proportion of water required varies with the fineness, age, or other conditions of the cement, and the temperature of the air, but is approximately as follows: for briquets of neat cement, Portland, about 25%; natural, about 30%. For briquets of one part cement, one part sand, about 15% of total weight of sand and cement. For briquets of one part cement, three parts sand, about 12% of total weight of sand and cement. The object is to produce the plasticity of rather stiff plasterer's mortar.

An average of five briquets may be made for each test, only those breaking at the smallest section to be taken. The briquets should always be put in the testing machine and broken immediately after being taken out of the water, and the temperature of the briquets and of the testing-room should be constant between 60 and 70° F.

The stress should be applied to each briquet at a uniform rate of about 400 pounds per minute, starting each time at 0. With a weak mixture one half the speed is recommended.

WEIGHT

The relation of the weight of cement to its tensile strength is an uncertain one. In practical work, if used alone, it is of little value as a test, while in connection with the other tests recommended it is unnecessary, except when the relative bulk of equal weights of cements is desired.

We recommend that the cubic foot be substituted for the bushel as the standard unit, whenever it is thought best to use this test.

SETTING

The rapidity with which a cement sets or loses its plasticity furnishes no indication of its ultimate strength. It simply shows its initial hydraulic activity.

For purposes of nomenclature, the various cements may be divided arbitrarily into two classes, namely; quick setting, or those that set in less than one half hour; and slow setting, or those requiring one half an hour or more to set. The cement must be adapted to the work required, as no one cement is equally good for all purposes. For submarine work a quick setting cement is often imperatively demanded, and no other will answer, while for work above the water line less hydraulic activity will usually be preferred. Each individual case demands special treatment. The slow setting natural cements should not become warm while setting, but the quick setting ones may, to a moderate extent, within the degree producing cracks. Cracks in Portland cement indicate too much carbonate of lime, and in the Vicat cements too much lime in the original mixture.

SAMPLING

There is no uniformity of practice among engineers as to the sampling of the cement to be tested, some testing every tenth barrel, others every fifth, and others still every barrel delivered. Usually, where cement has a good reputation, and is used in large masses, such as concrete in heavy foundations or in the backing or hearting of thick walls, the testing of every fifth barrel seems to be sufficient; but in very important work, where the strength of each barrel may in a great measure determine the strength of that portion of the work where it is used, or in the thin walls of sewers, etc., every barrel should be tested, one briquet being made from it.

In selecting cement for experimental purposes, take the samples from the interior of the original packages, at sufficient depth to

insure a fair exponent of the quality, and store the same in tightly closed receptacles impervious to light or dampness until required for manipulation, when each sample of cement should be so thoroughly mixed, by sifting or otherwise, that it shall be uniform in character throughout the mass.

SIEVES

For ascertaining the fineness of the cement, it will be convenient to use three sieves, viz:

No. 50 (2500 meshes to the square inch), wire to be no. 35 Stub's wire gage.

No. 74 (5476 meshes to the square inch), wire to be of no. 37 Stub's wire gage.

No. 100 (10,000 meshes to the square inch), wire to be of no. 40 Stub's wire gage.

The object is to determine by weight the percentage of each sample that is rejected by these sieves, with a view not only of furnishing the means of comparison between tests made of different cements by different observers, but indicating to the manufacturer the capacity of his cement for improvement in a direction always and easily within his reach. Tests for strength should be applied to the cement as offered in the market, as well as to that portion of it which passes the no. 100 sieve.

For sand, two sieves are recommended, viz:

No. 20 (400 meshes to the square inch), wire to be of no. 28 Stub's wire gage.

No. 30 (900 meshes to the square inch), wire to be of no. 31 Stub's wire gage.

These sieves can be furnished in sets, as follows, an arrangement having been made with a manufacturer of such articles, by which he agrees to furnish them of the best quality of brass wire cloth, set in metal frames, the cloth to be as true to count as it is possible to make it, and the wire to be of the required gage. Each set will be inclosed in a box, the sieves being nested.

Set A, three cement sieves, to cost $4.80:

No. 100	7 inch diameter
No. 74	6½
No. 50	6

Set B, two sand sieves, to cost $4:

No. 30	8 inch diameter
No. 20	7½

STANDARD SAND

The question of a standard sand seems one of great importance, for it has been found that sands looking alike and sifted through the same sieves give results varying within rather wide limits.

The material that seems likely to give the best results is the crushed quartz used in the manufacture of sandpaper. It is a commercial product, made in large quantities and of standard grades, and can be furnished of a fairly uniform quality. It is clean and sharp, and, although the present price is somewhat excessive (3 cents per pound), it is believed that it can be furnished in quantity for about $5 per barrel of 300 pounds. As it would be used for tests only, for purposes of comparison with local sands, and with tests of different cements, not much of it would be required. The price of the German standard sand is about $1.25 per 112 pounds, but the article, being washed river sand, is probably inferior to crushed quartz. Crushed granite can be furnished at a somewhat less rate than quartz, and crushed trap for about the same as granite, but no satisfactory estimate has been obtained for either of these. The use of crushed quartz is recommended by your committee, the degree of fineness to be such that it will all pass a no. 20 sieve and be caught on a no. 30 sieve. Of the regular grade, from 15% to 37% of crushed quartz, no. 3 passes a no. 30 sieve, and none of it passes a no. 50 sieve. As at present furnished, it would need resifting to bring it to the standard size; but, if there were sufficient demand to warrant it, it could undoubtedly be furnished of the size of grain required at little, if any, extra expense.

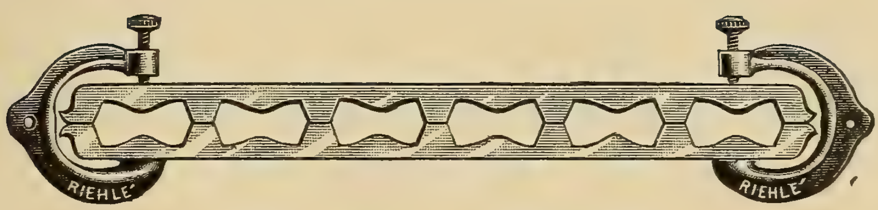
A bed of uniform, clean sand of the proper size of grain has not been found, and it is believed that to wash, dry, and sift any of the available sands would so greatly increase its cost that the product would not be much cheaper than the crushed quartz, and would be much inferior to it in sharpness and uniform hardness of particles.

MOLDS

The molds furnished are usually of iron or brass, the price of the former being $2, and of the latter $3 each. Wooden molds, if well oiled to prevent their absorbing water, answer a good purpose for temporary use, but speedily become unfit for accurate work. A cheap, durable, accurate, and non-corrodible mold is much to be desired. Molds are made for holding one, two or more briquets. A common form is shown in pl. 27.

Plate 27

To face p. 742



Brass mold for making cement briquets (Riehle Bros.)

CLIPS

For using the clips recommended in the preliminary report it was found in some instances that the specimens were broken at one of the points where they were held. This was undoubtedly caused by the insufficient surface of the clip, which, forming a blunt point, forced out the material. Where the specimens were sufficiently soft to allow this point to be embedded, they broke at the smallest section, but, when hard enough to resist such embedding, they showed a wedge-shaped fracture at the clips. To remedy this, the point should be slightly flattened, so as to allow of more metal surface in contact with the briquet. Clips made in this way have been used, and good results obtained.

To adapt the one inch clips of the Riehle machine, only a slight amount of work is necessary; the ends being rounded, will admit the proposed new form of briquet, and yet not prevent the use of the old one, thus allowing comparative tests of the two forms to be made without changing the clips.

There should be a strengthening rib upon the outside of the clips to prevent them from bending or breaking when the specimens are very strong.

The clips should be hung on pivots so as to avoid as much as possible cross strain upon the briquets.

MACHINES

No special machine has been recommended, as those in common use are of good form for accurate work, if properly used, though in some cases, they are needlessly strong and expensive. Machines with spring balances are to be avoided as more liable to error than others.

It is by no means certain that there exists any great difference in well made machines of the standard forms given.

AMOUNT OF MATERIAL

The amount of material needed for making five briquets of the standard size recommended is: for the neat cements, about one and two thirds pounds; and for those with sand, in the proportion of three parts of sand to one of cement, about one and one quarter pounds of sand and six and two thirds ounces of cement.

German specifications for standard Portland cement tests

Definition. Portland is a product resulting from the vitrification of a thorough mixture of material, whose principal component

parts are lime and alumina, and the grinding of the vitrified material to a fine powder.

1 Packing and weights: As a rule Portland cement is to be packed in standard barrels of 180 kilograms (397 pounds), gross weight, and about 170 kilograms (374 pounds), net weight, and in half standard barrels of 90 kilograms (198 pounds), gross weight and about 83 kilograms (133 pounds), net weight. The gross weight is to be marked on the barrels. If the cement is called for in bags or barrels of other weight, the gross weight of the same must be clearly marked upon the packages. Losses and variations in weight of the single packages up to 2% of the same will be allowed. Barrels and sacks, in addition to the weight shall show in legible writing the name and trade mark of the manufacturer.

2 Time of setting: Slow or quick setting cement may be called for according to the use for which the cement is to be put. Cements which do not set in less than 2 hours, are to be considered slow setting cements.

3 Constancy of volume: Portland cement shall be of constant volume. As a preliminary test, admitting of forming a rapid opinion, the heating test is recommended. The decisive test shall be that a paste of neat cement made on a glass plate protected against drying and placed under water after 24 hours, shall not show after the lapse of a longer period of time any blowing cracks, or change of shape.

4 Fineness of grinding: Portland cement shall be so finely ground that a batch of the same shall not leave a residue of more than 10% upon a sieve of 900 meshes per square centimeter (5806 meshes per square inch). The thickness of the wire of the sieve shall equal half the space between the wires. For test 100 grams (3½ ounces) of cement shall be used.

5 Tests of strength: The cohesive power of Portland cement shall be determined by the testing of a mixture of cement and sand. The tests shall be both tensile and compressive, made according to a uniform method, with test pieces of the same form and cross-section, and with the same apparatus. At the same time a determination of the strength of the neat cement is to be recommended.

6 Tensile and compressive strength: Good slow setting cement, in the proportion of three parts by weight of standard sand to one part of cement shall have when tested, after 28 days' hardening (one in air and 27 in water), a minimum tensile strength

of at least 16 kilo. q. c. m. (16 kilograms per square centimeter, 227 pounds per square inch). The compressive strength shall be at least 160 kilo. q. c. m. (2270 pounds per square inch).

Cement which shows a higher tensile or compressive strength in many cases of a greater addition of sand, from this point of view, as well as on account of its greater strength for the same amount of sand, is entitled to a correspondingly higher price.

For slow setting cements the strength after 20 days is less in general than the one above specified, therefore, in giving the results of tests, the time of setting shall also be given.

The tests shall be made in the following manner.

To determine the time of setting cement, a slow setting neat cement shall be mixed three minutes, and a quick setting neat cement shall be mixed one minute with water to a stiff paste. A cake about 1.5 cm (.59 inch) thick, with thin edges, shall be formed of this paste on a plate of glass. The consistency of the cement paste for this cake shall be such that, when brought with a trowel on the plate, the paste will only begin to run toward the edges of the same after the paste has been repeatedly jarred. As a rule 27% to 30% water will suffice to give the necessary consistency to the paste. As soon as the cake is sufficiently hardened, so that it will resist a slight pressure of the finger nail, the cement is to be considered as having set.

For the exact determination of the time of setting, and for determining the beginning of the time of setting, which latter is of importance in the case of quick setting cements, since they must be worked up before they begin to set, a standard needle 300 grams (10 ounces) in weight and 1 square mm (.00155 square inch) in cross-section, is used. A metal ring 4 cm (1.575 inch) in hight and 8 cm (3.15 inches) clear diameter (inside) is placed on a glass plate, filled with cement paste of the above consistency and brought under the needle. The moment at which the needle is no longer capable of completely penetrating the cement cakes is considered the beginning of the time of setting. The time elapsing between this and the moment when the standard needle no longer leaves an appreciable impression on the hardened cake is considered the time of setting.

For making the heat test (3) a stiff paste of neat cement and water is made, and from this cakes 8 cm (3.15 inches) to 10 cm (3.94 inches) in diameter and 1 cm (.394 inch) thick are formed on a smooth, impermeable plate, covered with blotting paper. Two of these cakes, which are to be protected against drying,

in order to prevent drying cracks, are placed, after the lapse of 24 hours, or at least only after they have set, with their smooth surfaces on a metal plate and exposed, for at least one hour, to a temperature of from 110° C to 120 (230 to 248 F) until no more water escapes. For this purpose the drying closets in use in chemical laboratories may be utilized. If, after this treatment, the cakes show no edge cracks, the cement is to be considered in general of constant volume. If cracks do appear, the cement is not to be condemned, but the results of the decisive test with the cakes hardening on glass plates under water must be waited for. It must, however, be noticed that the heat test does not admit of a final conclusion as to the constancy of volume of those cements which contain more than 3% of calcium sulfate (gypsum) or other sulfur combinations.

For making the final test, the cake made for the purpose of determining the time of setting, for slow setting cements, is placed under water after the lapse of 24 hours, but, at all events, not until after it is set. For quick setting cements this can be done after a shorter period. The cakes, especially those of slow setting cement, must be protected against drafts and sunshine until their final setting. This is best accomplished by keeping them in a covered box lined with zinc, or under wet cloths. In this manner the formation of heat cracks is avoided, which are generally formed in the center of the cake, and may be taken by an inexperienced person for cracks formed by blowing.

In order to obtain concordant results in the tests, sand of uniform size of grain and uniform quality must be used. This standard sand is obtained by washing and drying the purest quartz sand obtainable, sifting the same through a sieve with 60 meshes per square cm (387 per sq. inch), thereby separating the coarsest particles, and by removing from the sand so obtained, by means of a sieve of 120 meshes per square cm, the finest particles. The diameter for the wires of the sieve shall be .38 mm, and .32 mm respectively. Since not all quartz sand even under the same method of treatment, gives the same resulting strengths in the mortars, one must know whether the standard sand at one's disposal gives concordant results with the standard sand furnished by the German society of cement manufacturers and also used at the royal testing station at Berlin (Charlottenburg).

For each test, in order to obtain correct average results, at least six test pieces are to be made. Tensile test pieces can be made either by hand or by machinery.

HAND WORK

On a metal or thick glass plate five sheets of blotting paper soaked in water are laid, and on these are placed five molds wetted with water; 250 grams (8.75 ounces) of cement and 750 grams of standard sand are weighed and thoroughly mixed dry in a vessel. Then 100 ccm (100 grams or 35 ounces) of fresh water are added, and the whole mass thoroughly mixed for five minutes. With the mortar so obtained the molds are at once filled, with one filling, so high as to be rounded on top, the mortar being well pressed in. By means of an iron trowel 5 to 8 cm (1.96 to 3.14 inches) wide, 35 cm (13.79 inches) long, and weighing about 250 grams, the projecting mortar is pounded first gently and from the sieve, then harder into the molds until the mortar grows elastic, and water flushes to the surface. A pounding of at least one minute is absolutely essential. An additional filling and pounding in of the mortar is not admissible, since the test pieces of the same cement shall have the same densities at the different stations. The mass projecting over the mold is carefully taken off, and the test piece placed in a box lined with zinc, which is to be provided with a cover, to prevent a non-uniform drying of the test pieces at different temperatures. 24 hours after being made, the test pieces are placed under water, and care has to be taken that they remain under water during the whole period of hardening.

MACHINE WORK

After the mold, provided with a guide mold, has been clamped, by means of set screws, on the bedplate of the pounding machine, for each test, 180 grams of the mortar, made as above, are placed in the mold and the iron follower is set in. By means of Böhme's hammer apparatus, with a hammer weighing 2 kilograms, 150 blows are struck on the follower.

After the guide mold and follower have been removed, the test piece is scraped off, smoothed, taken with the mold from the bedplate and for the rest treated as for the hand work. By accurately following the directions given above, hand and machine work give well concording results. In all cases of doubt the machine work is to be decisive.

COMPRESSIVE TESTS

In order to obtain concordant values in compression tests at different stations, machine making is necessary. 400 grams of neat cement and 1200 grams dry standard sand are thoroughly

mixed dry in a vessel, and 160 ccm of water are added thereto, and then the mortar is thoroughly mixed for five minutes. Of this mortar 850 grams are placed in the cubic molds, provided with guide mold, and the mold is then screwed on the bedplate under the pounding machine. The iron follower is placed in the form, and, by means of Böhme's trip hammer, 150 blows are struck, by a hammer weighing 2 kilograms.

After removing the guide mold and follower, the test piece is smoothed off, with the mold from the bedplate, and for the rest treated as for hand work, as given above.

MAKING TEST PIECES OF NEAT CEMENT

The inside of the molds is slightly oiled, and the same are placed on a metal or glass plate without blotting paper. 1000 grams of cement are weighed out, 200 grams of water are added, and the whole mass thoroughly mixed for five minutes (best with pestle). The forms are well filled (rounded), and then proceed as for hand work as given above. The molds can only be taken off after the cement has sufficiently hardened. Since, by the pounding in of the neat cement, test pieces of uniform consistency are to be obtained, for finely ground or quick setting cements, the amount of water must be correspondingly increased. The volume of water is always to be stated in giving the strength obtained.

TREATMENT OF TEST PIECES AT TIME OF TESTING

All specimens are to be tested directly after their removal from the water. Since the time of testing is of influence on the result in tensile tests, the increase of load shall be 100 grams per second. The mean of the four best results shall be considered the final tensile strength. In testing compression pieces, the pressure is always to be exerted on two side faces of the cube, but not on the bottom or top. The mean of the four highest tests shall be considered as the final compressive strength.

Abstract from French specifications for Portland cement

CHEMICAL ANALYSIS

The cement must not contain more than 1% of sulfuric acids or sulfids in determinable proportion. Cements containing more than 4% of ferric oxid, or in which the ratio of the combined silica and alumina to the lime is less than .44, are to be regarded as doubtful.

MIXING THE MORTAR

In mixing the mortar for testing, sea water is specified, and both air and water are to be maintained at a temperature of 15° to 18° C (59–64.4 F) during the continuance of the experiments. The quantity of water is ascertained by a preliminary experiment, and the four following tests are given as an indication whether the proportion of water added is correct:

1 The consistence of the mortar should not change if it be gaged for an additional period of three minutes after the initial five minutes.

2 A small quantity of the mortar dropped from the trowel on a marble slab from the hight of about .50 meter (1.64 feet) should leave the trowel clean, and retain its form approximately without cracking.

3 A small quantity of the mortar worked gently in the hands should be easily molded into a ball, on the surface of which water should appear. When this ball is dropped from the height of .50 meter (1.64 feet) it should retain a rounded shape without cracking.

4 If a slightly smaller quantity of water be used, the mortar should be crumbly and crack when dropped upon the slab. On the other hand the addition of a further quantity of water — 1%–2% of the weight of the cement — would soften the mortar, rendering it more adhesive, and preventing it from retaining its form when allowed to fall on the slab. It is recommended to commence with a rather smaller quantity of water than is ultimately required, and then to make fresh mixings with a slight additional quantity of water.

The mortar is to be mixed with a trowel for five minutes on a marble slab.

STRENGTH

The form of briquet and method of molding are the same as in the German specifications; the breaking section is 5 sq. cm (.775 square inch). Six briquets are broken after an interval of seven days, six after 28 days, and the remaining six after 84 days. The mean of the three highest figures of each series of tests is taken as the tensile strength of the cement under examination. The minimum strength specified for the neat cement in seven days is 20 kilograms per sq. cm (284.5 pounds per square inch); in 28 days, 35 kilograms per sq. cm (498 pounds per square inch); and at least 45 kilograms per sq. cm (640

pounds per square inch) at the end of 84 days. If, however, the strength in 28 days is not more than 5 kilograms per sq. cm (71.12 pounds per square inch) in excess of that at seven days, then it must be at least 55 kilograms per sq. cm (727.8 pounds per square inch) in 28 days, and in any case where this is not attained in 28 days it must be exceeded in 84 days.

Tests of cement mixed with sand are also specified. The standard sand is produced by crushing quartzite obtained from the quarries near Cherbourg, and sifting it through sieves of 64 and 144 meshes per sq. cm (413 and 929 meshes per square inch). That which remains between these two sieves is washed and dried, and constitutes the standard sand. 375 grams (13.25 ounces) of this sand is mixed with 125 grams (4.41 ounces) of cement, and water is added in the proportion of 12 parts by weight to 100 parts of sand and cement combined. The sand and cement are first carefully mixed in a basin or capsule, then the whole of the sea water is added at once, and the mixture stirred with a spatula for 5 minutes. At the expiration of seven days the strength of the sand cement briquets should be at least 8 kilograms per sq. cm (113.78 pounds) and in 28 days 15 kilograms per sq. cm (213.35 pounds per square inch). In 28 days the strength should exceed that at seven days by 2 kilograms per sq. cm (28.45 pounds per square inch). In 84 days the strength must be greater than at 28 days, and at least 18 kilograms per sq. cm (256 pounds per square inch). The 84 day tests are only considered indispensable for those cements which may have stood the two previous tests; but if, while the cement is in store, the 84 day tests should be unsatisfactory, it may be rejected.

FINENESS OF GRINDING

The degree of fineness to which the cement must be ground is not specified, it being considered that very fine grinding increases the strength chiefly during the duration of the tests, and that subsequent increase of strength is less with fine than with coarse cement.

TIME OF SETTING

This practically agrees with the German specifications. Any cement commencing to set in less than 30 minutes, or failing to commence to set within three hours is to be rejected; and the final set must have taken place within 12 hours. In each case the time is reckoned from the moment the water is poured on the cement.

Books relating to cement

The following list gives the titles of a number of works, which will enable those desiring it to obtain more detailed information concerning the technology of cement manufacture than it is possible to give within the limits of this report.

Butler, D. B. Portland cement: its manufacture, testing and use. N. Y. 1899.

Candlot. Ciments et chaux hydrauliques. Paris 1891.

Clarke, E. C. Experiments with Rosendale and Portland cements. (*see* Trans. Am. soc. civ. eng. Oct. 1893. Ap. 1885; also June 21 and Nov. 1885)

Cummings, U. American cements. Bost. 1898.

Gary, M. Raumbeständigkeit von zehn Portland cementen. Kgl. Tech. Versuchsanstalten. 1899. Erganz. heft 1.

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GEOLOGY OF NEW YORK LIMESTONES

Limestones are found in New York from the oldest to the youngest formations. Some, like those of the pre-Cambrian, are often local in their extent; while others, like those of the Helderberg, extend from one end of the state to the other.

The formations containing limestone in New York state are the pre-Cambrian, Calciferous, Chazy, Trenton, Clinton, Niagara, Onondaga, Lower Helderberg, Upper Helderberg, Goniatite, Tully, Quaternary marls.

The most important of these are the Calciferous, Trenton, Niagara, Lower Helderberg and Upper Helderberg. The Calciferous and Niagara sometimes contain sufficient magnesia to be called true dolomites, and this fact, together with the freedom from impurities which they exhibit at some localities, gives them a special usefulness.

Calciferous

The rock of this formation is frequently highly magnesian, and a high percentage of silica is likewise not uncommon in it. On this account it is sometimes called Calciferous sandrock.

The Calciferous limestones occur as isolated patches or belts in several parts of the state, and show considerable variation in character. With few exceptions they are magnesian and indeed may pass into true dolomites. On the other hand, they are often highly silicious, so much so as to render them practically worthless for any of the uses considered in this report. Again they may run very low in silica, as near Glens Falls.

Cambro-Silurian limestones appear in the southeastern portion of the state in Orange county, extending northeastward across the county to the Hudson river, and across it through Dutchess into Columbia county.

Another series of belts begins in Westchester county and extends from New York city northward to the county line and through Putnam and Dutchess counties to Pawling and beyond.

The character of these is mentioned in the county descriptions. These limestones are equivalent to the Stockbridge, and represent the Acadian-Trenton periods.

A belt of Calciferous limestone extends from Saratoga westward through Montgomery, Fulton and Herkimer counties.

With the exception of the outcrops in the vicinity of Glens Falls the rock is usually very silicious and is known as sandrock.

In Herkimer, Fulton, Saratoga and Montgomery counties this formation underlies a considerable area and often forms cliffs along the rivers and creeks. Its normal character is fairly constant, viz a light bluish gray, fine grained, massively bedded sandy limestone. The weathered surfaces are generally a dirty buff. The following localities are noted by N. H. Darton as affording good exposures.[1]

About Middleville, Little Falls and northwestward along the fault scarp, on East Canada creek, about St Johnsville, along the Mohawk from Canajoharie to the 'Noses,' the quarries at Tribeshill along the Mohawk from Amsterdam to Hoffmanns ferry, also in southwestern Saratoga county and west of Saratoga Springs.

According to Walcott[2] the section of Calciferous near Saratoga involves:

	Feet
Massive layers of steel gray, more or less arenaceous limestone	125
Massive bedded, slightly magnesian, gray and dove colored limestone	35
Unfossiliferous, impure, compact, more or less silicious limestone	95
Dark gray, evenly bedded limestone	50
Oölitic limestone	30

Chazy

The Chazy limestone first appears at Saratoga and extends northward along the Champlain valley to Montreal. The area

[1] 13th an. rep't N. Y. state geol. p. 612.
[2] Bul. 81. U. S. geol. sur. p. 346.

is probably a continuous one, though not exposed at all points. The most prominent exposures of the Chazy are in the quarries of the Chazy marble lime co. and William Goss, and at Grand Isle. The rock is a gray, subcrystalline limestone, and affords an excellent lime. The average thickness of the formation according to Brainerd and Seely is about 700 feet. The character of the stone is quite uniform. The Chazy limestone is not found in the Mohawk valley and thins out in the central and western part of the state.

An analysis of the Chazy limestone from the quarry of the Chazy marble lime co. at Chazy, shows the high degree of purity of this limestone which is used in the manufacture of lime.

Silica	.72
Ferric oxid and alumina	.39
Lime	53.9
Magnesia	1.44
Carbon dioxid	43.92
	100.37

The stone is also available for the manufacture of Portland cement.

Trenton

The Trenton limestones involve several different members, viz, Birdseye, Black river and Trenton, the last being the uppermost. The most southern area is a small patch of impure, fossiliferous limestone along the river road four miles north of Newburgh.

An important belt extends southward along the Champlain valley, then along the Mohawk to Little Falls and thence northwestward to Watertown. Beds of the same age also occur east of Lake Champlain and extend southward into Washington county.

In this belt they are often metamorphosed or folded, but along the lake shore, specially along the margin of the Adirondack

island of crystalline rocks, the beds are little disturbed and sometimes highly fossiliferous. The Birdseye rarely exceeds 6 feet in thickness. It is a pure dove colored to dark gray limestone with conchoidal fracture and often containing veins of quartz or calcite.

The total thickness of the Trenton in the Champlain valley is 230 feet, and it overlies the Chazy. Quarries have been opened up at Isle La Motte, Plattsburg, Larrabees point, and Crown point.

The Black river limestone in the Champlain valley is locally known as Isle La Motte marble. It has a varying thickness from 35 feet on Larrabees point to 75 feet on Crown point and 20 feet at Plattsburg. The stone is usually heavy bedded, tough, compact and black.

The Trenton proper is exposed at Crown Point (N. Y.) where it has a thickness of 150 feet. It is usually thin bedded and shaly but contains several beds of purer limestone.

Beginning at a point about one half mile south of Smiths Basin in Washington county, the Trenton limestone extends northward, passing east of North Granville, east of Whitehall, which lies on the western edge of the belt, then northward in a belt from one mile to half a mile wide, past Benson Landing and northward into Vermont. The town of Vergennes lies on the eastern border of the belt. Another belt of this same rock is found farther south in Washington county, extending from a point half a mile north of Easton Corners up to and for half a mile north of Argyle. Throughout its extent the rocks of these two more or less continuous belts have been highly disturbed by dynamic forces. They are much folded and crushed and at times assume a very slaty structure. The limestone is generally fine grained and of a black color, is traversed by numerous veins of white calcite and is frequently of high purity. It is mined at Smiths Basin and also west of Fairhaven on the Vermont line. At both of these localities the stone has been quarried for limemaking and flux.

In the Mohawk valley only the Birdseye and Trenton members are present. The Birdseye member is in greater part a fine grained, dove colored stone, and weathers light gray, and the beds are generally moderately heavy. The exposures are common in the Mohawk valley and have been quarried at a number of localities. Underlying this rock is the Calciferous sandstone.

According to Darton[1] the formation reaches its maximum thickness at Fort Plain, where it is about 9 feet thick. It then decreases westward to 7 feet near St Johnsville. It is 5 feet on East Canada creek, 4 feet around Little Falls and to the southeastward, and 5 to 6 feet on West Canada creek about Middleville, Newport and Cold creek.

At Ingham Mills the rock is well exposed in Butler's lime quarry. At this point nearly 15 feet of a good grade of stone is exposed. At Canajoharie the Trenton member of the group appears. Excellent exposures occur near Amsterdam and at Glens Falls. At this latter locality the quarries are of special importance. The Trenton limestone member is found extending eastward from Oneida county to Glens Falls. At times the rock is massive as at Tribeshill, at others it is somewhat shaly. The thickness in the quarries at Tribeshill is 12 to 14 feet of massive stone. Other exposures also occur in the quarries about Amsterdam and again in quarries 2 miles northwest of Hoffmans ferry, where about 20 feet of a soft, highly fossiliferous limestone is exposed.

A belt of Trenton occurs west of Saratoga and is well exposed at Howland's mill 3 miles due west — southwest from Saratoga Springs. The section here shows 20 feet of limestone.

At Glens Falls the Trenton limestone is well exposed on both banks of the Hudson, and is of much importance, being used for building stone lime and Portland cement.

Darton gives the following section of it.

	Feet
Thin bedded black limestones in beds 3 to 8 in.	10
Black marble 10 to 14 in. beds	3

[1] 15th an. rep't N. Y. state geol. p. 516.

	Feet
Black marble one or two in. beds	13
Black, massive, fine grained limestone. In floor of quarry	3
Dark gray, fine grained limestone	25
Black, compact limestones with slaty layers.	

It overlies the Chazy. There are also extensive outcrops of it around Hoosick Falls, but at this point the stone is apt to be slaty.

The Trenton rocks also extend northward from the Mohawk valley to Watertown. They are quarried at Prospect, Oneida, Port Leyden, Boonville and Watertown. The Trenton limestone formation is dark gray to black and is often fossiliferous. The central part of the Trenton formation is apt to be shaly in places, while the Birdseye limestone is massive and heavy bedded. The upper part of the Trenton formation or Trenton limestone proper is a lighter gray limestone and finely crystalline in its nature. This member is quarried at Prospect.

Niagara

In Schoharie county we find the eastern end of this formation. Its thickness is not more than 5 feet, and it is usually a dark gray, massive limestone. An exposure of it can be seen at Howe Cave just below the cement quarries, of which it forms the floor.

The Niagara limestone also appears in Oneida county north of Clayville and extends westward with increasing width to the Niagara river. In Wayne county in the town of Butler[2] it is a dark blue, fine grained, compact limestone and is usually thin bedded. It has been used at this point for burning lime. Other occurrences are at Rose on the head waters of Sheldon creek and in the towns of Marion and Walworth. It has been quarried at many points in Wayne county for the manufacture of lime.

In Monroe county the northern edge of the limestone passes through the towns of Penfield, Brighton, Gates, Ogden and

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[1] Darton, N. H. Helderberg limestones and associated formations in eastern New York. (*see* 13th an. rep't N. Y. state geol. p. 218)

[2] Hall, James. Geol. 4th dist. N. Y. p. 84.

Sweden. The outcrops at these points generally represent the beds of the upper magnesian member, and its weathered surface presents a characteristic spongy appearance.

The Niagara formation presents two types of lime rock: the one a dark gray, subcrystalline stone, which is used for lime and building purposes, the other a gray brown, crystalline rock with numerous cavities and containing a high percentage of magnesia.

The area in which the Niagara limestone is found is more restricted than that of most of the other limestone formations of the state. The upper member of this formation is known as the Guelph limestone but is not coextensive with the lower member. It forms a lenticular bed about 20 miles long and extends from Rochester westward. In the vicinity of Rochester quarries have been opened in it at New Brighton and Gates. As exposed in these quarries, it is a grayish brown, finely crystalline limestone containing numbers of small cavities. The peculiar feature of this rock is that it contains a large amount of magnesia and a very low silica percentage, making it very adaptable for use in the lining of Bessemer converters.

Lower Helderberg

This formation as formerly described includes several distinct members which are known as the Tentaculite, Waterlime, Pentamerous, lower or Catskill shaly, Becraft or upper Pentamerous, and upper shaly. The formation is a widely distributed one within the state and of considerable economic importance, containing the hydraulic limestones which are extensively developed at Rosendale near Kingston in Ulster county.

In his recent classification[1] Dr J. M. Clarke considers the Tentaculite limestone, which in this bulletin is discussed as the base of the Lower Helderberg, to be the highest member of the Salina. If Dr Clarke's grouping be accepted, then the most westerly outcrops of the Lower Helderberg in this state are in

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[1] Mem. 3. N. Y. state mus.

the neighborhood of Chittenango Falls, Madison co.; and the statements in the text should be correspondingly qualified.

The members of this formation enter the state at the southeastern corner just east of Port Jervis (N. Y.) following up the southeastern side of the Neversink river, Bashers kill, and Rondout creek, throughout this whole distance resting on the Shawangunk grit which forms the crest of the Shawangunk mountain. From Kingston the same formation extends northward past Catskill to New Baltimore, where it then swings to the northwest, extending as far as New Salem in Albany county. At this point it becomes very narrow; it however appears again as a somewhat broad belt just west of Meadowdale in the same county and then extends westward as far as Central Bridge in Schoharie county, and from there in a slightly northwest direction past Sharon Springs, Dennisons Corners, Oneida, Syracuse, and westward to Niagara Falls. Up to Dennisons Corners the formation, though of considerable thickness, does not cover a very broad belt, owing to the perpendicular escarpment which it forms, but its thickness remains about the same from Syracuse westward to Buffalo, and the elevation of the escarpment decreases.

The Tentaculite limestone forms the lower member of the series and is generally a dark colored, thin to thick bedded, at times argillaceous limestone. It seldom reaches a condition of great purity and aside from the cement beds which are worked separately its chief use has been for building purposes.

As the Helderberg limestones are of considerable thickness in New York state, it may be well to mention them in detail. This can best be done by quoting from the report of N. H. Darton.[1]

The Helderberg limestones attain their greatest development in eastern New York, and the thickness reported by Davis of about 300 feet in the Catskill region is the maximum. They thin gradually southward in New York, but expand again in New Jersey. In the Helderberg mountains there are 200 feet and at

[1] Report on the relations of the Helderberg limestones and associated formations in eastern New York. (*see* 13th an. rep't N. Y. state geol. p. 204)

Schoharie not over 240 feet. Westward from Schoharie the thickness decreases very gradually. The members constituting the formation in its typical development, beginning at the top, are a pure semicrystalline, massive, very fossiliferous limestone, a thick series of shaly limestone, and the basal series, thin bedded dark limestones of the Tentaculite beds. On Catskill creek a higher member of impure shaly limestone comes in above the pure, massive beds, thickens rapidly and continues southward to and through New Jersey. The Helderberg formation preserves its typical characters with some local variations in thickness to a few miles west of Cherry Valley. Then the upper limestone beds thin out, and on the road from West Winfield to Litchfield, in the southwestern corner of Herkimer county, the Pentamerus beds lie directly under the Onondaga limestone . . . The upper members of the Helderberg limestones . . . come in again westward and are finely exposed at Oriskany Falls.[1] . . Here 120 feet of beds are exposed in and about the quarries, of which 50 feet are quite distinctively of the Tentaculite beds, 40 feet of gray beds in greater part of Pentamerus limestone age, but merging into the character of the lower beds, a few feet of beds with mixed Pentamerus and shaly limestone fauna, and, at the top, 25 feet of gray subcrystalline rock containing a shaly limestone fauna. 25 miles west of Perryville, Madison co., this condition has continued, the lower members expanding apparently at the expense of the Pentamerus beds and the upper members giving place to Pentamerus beds. At this locality the Onondaga limestone was seen lying on a few feet of dark gray limestones containing Pentamerus, with a thin local intervening layer of Oriskany at one point, which gave place to a great mass of thin bedded gray limestone below.

The different members preserve their distinctive characters more or less, though there are occasional slight local variations.

The so-called Scutella beds are the uppermost member southward to near Catskill. They are light colored, coarsely semicrystalline, massively bedded, highly fossiliferous limestone blotched with calcite replacement of fossils, of which the most conspicuous is the so-called Scutella. These are the cups or pelvis of a crinoid, having a diameter in greater part from one to two

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[1] *See also* Williams, S. G. The westward extension of rocks of the Lower Helderberg age in New York, Am. jour. sci. 3d ser. 31: 139–45; abstract Proc. Am. ass'n adv. sci. 34: 235, 236; Am. nat. 1886. 20: 373.

inches, and the white calcite of which they consist contrasts strongly with the light bluish gray of the containing limestone. In the Schoharie region where these cups characterize the lower beds of the member, the overlying layers have been called the upper Pentamerus beds from the fossil P. pseudogaleatus which they contain, and this name has been employed to some extent to comprise all the beds. In the eastern extension of the formation the distinction is lost. About Catskill, Davis designates the lower layers the "Encrinal" and the upper layers the "upper Pentamerus" limestone. Owing to the inappropriateness of the name Scutella and the varying significance of the other names that have been employed, the geographic name of Becraft limestone has been suggested to me by Prof. Hall. The name is from Becraft mountain in Columbia county, where the rock is typically developed. The Becraft limestone has a thickness of 10 to 15 feet near Schoharie, and the amount does not vary greatly eastward to the Helderberg mountains and by Clarksville, Aquetuck and Coxsackie. Thence it increases rapidly, and Davis reports a thickness of 120 feet below Leeds, the upper 10 feet consisting of impure and sandy or shaly layers. There are, as Davis suggests, many local slips in this section, and my estimate of the thickness of the purer limestone would be about 60 feet.

"In the Rondout region the Becraft limestone is 40 feet thick and the upper shaly beds 100 to 150 feet thick. In the ridge just east of Whiteport there are 30 feet of Becraft limestone." About Rosendale and southward no exposures have been noted by Darton. "Underlying the Becraft limestone throughout are the lower shaly beds, consisting of thin bedded, impure, highly fossiliferous limestone with some shale beds." At some localities though, as for instance westward on the Fox kill above Gallupville, it is in greater part a massive, relatively pure limestone. In Greene and Ulster counties it has the character of the upper shaly beds, with a more or less slaty cleavage and outcropping in ragged ledges, in some cases closely resembling the lighter colored outcrops of the Esopus slate. Its thickness from Schoharie eastward is about 80 feet, and there and elsewhere in the great Helderberg escarpment it constitutes a steep slope between

the Scutella and Oriskany shelf above the Pentamerus escarpment below. Its thickness apparently decreases somewhat in the Kingston-Rosendale region, but it retains its characteristics.

The Pentamerus or lower Pentamerus are the most conspicuous members of the lower Helderberg formation. They give rise to the great escarpment which marks the eastern edge of the Helderberg formation as it passes along through central New York.

The beds are mostly hard, massively bedded and vertically jointed limestones. The rock is generally bluish gray in color but weathering imparts a lighter tint to the surface. Partings of slate occur occasionally as well as lenses of chert, specially in the east and south.

The Pentamerus limestone is a quite uniform member, and its thickness does not vary greatly. "At Schoharie its thickness is between 60 and 70 feet, in the Helderbergs it is the same and a trifle more about Catskill, 80 feet according to Davis, 50 feet at Saugerties, 30 to 40 feet about Rondout, 70 to 100 feet about Rosendale, the maximum being in the ridge just northwest of the village. The Pentamerus beds are quite sharply demarked from those above and below them."

The finest exposures of the Pentamerus ledges are in the great escarpment of the Helderberg mountains near the Indian Ladder, where they rise in great cliffs surmounting steep slopes to an altitude of 700 feet above the plain lying to the north and east.

The Tentaculite beds are thin bedded, dark blue limestones, lying below the Pentamerus beds, and usually constituting the base of the Pentamerus escarpment or lying beneath its talus. The beds vary in thickness from an inch to a foot in greater part, but two or three inches is the average.

The Tentaculite beds have a thickness of 40 feet at Howe Cave and Schoharie, somewhat less in the Helderberg mountains and from 30 to 40 feet through the Catskill and Kingston regions. In the Rosendale region the amount is less.

There are several outliers of the Helderberg limestone, of which an important one is Becraft mountain.

The attenuated eastern extension of the great Salina formation is of variable character and thickness and may not be continuous throughout. Locally it consists of heavy beds of cement rock but generally it is composed of thin beds of more or less impure cement intercalated with thin bedded limestones of varying character.

"The cement beds attain their greatest development around Rondout and Rosendale, where they are extensively worked. The cement rock is a blue black, very fine grained, massively bedded deposit of calcareous magnesian and argillaceous materials and is of somewhat variable character and composition. The rock produces a cement of good quality only when the components bear certain relative proportions to each other. A characteristic feature of the rock is the light buff hue to which it weathers on the surface. At Rosendale there is a 21 foot bed of the cement at the base of the formation, then from 12 to 15 feet of mixed impure cement and limestone beds, then another cement bed 11 feet in thickness. Above these are the Tentaculite and Pentamerus.

These cement beds with some variations in thickness, and many in character, extend over a wide area from north of Whiteport through Rosendale to beyond Highfalls, outcropping in a belt about eight miles long and two and a half wide. At Highfalls there is an upper bed of cement, 15 feet thick and a lower bed 5 feet thick, separated by 3 feet of impure limestone. At Whiteport the upper cement bed is 12 feet thick, the lower from 15 to 20 and the intervening limestone 10 feet in thickness. How far they may extend under the overlying rocks to the westward is not known, and their southern termination has not been explored. To the northeast the cement thins out rapidly and gives place to impure cements and limestones, but it thickens again rapidly in the Rondout region. At Rondout there are two cement beds, the lower one is 22 feet thick and the upper 5 feet thick, with 3 feet of limestone and cement intervening. Northwest the lower cement bed thins.

In Onondaga county the cement beds are again prominent, and vary in thickness from 1 to 5 feet. Many of the quarries show two beds."

Upper Helderberg

This is the limestone series which is termed the Corniferous by many writers, but by others the upper member of the series is termed Corniferous and the lower member Onondaga. The formation usually rests on the Schoharie grit, Cauda Galli grit, or Oriskany sandstone, but in the western part of the state these are wanting. The formation is divisible into 3 members, viz:

1 The lower, or Onondaga graystone, which is coarsely crystalline and well adapted for building.

2 The Corniferous, which is a hard and durable limestone containing many chert nodules.

3 The Seneca blue limestone, the purest of the three, fine grained and dark blue.

The upper Helderberg rocks are quarried near Kingston, Ulster co., at Splitrock, near Syracuse, also at Auburn, Waterloo, Seneca Falls, Leroy, Williamsville and Buffalo.

The subdivisions of the Onondaga group gradually lose their physical and faunal characteristics in eastern New York, and the formation is in greater part a bluish gray subcrystalline, massive limestone with lenticular masses of chert in courses and irregularly disseminated. Darker colors occur locally, notably in the upper beds about Peoria (West Berne), which are very dark and coarsely crystalline. The chert is predominant in the upper beds, but it is usually present also in the lower beds. In places it is an inconspicuous feature but this is not often the case. Thin partings of shale occur rarely. About Saugerties the lower portion of the limestone is shaly and weathers buff. About Clarksville the lower members are very pure, free from chert and regularly bedded.

In Greene and Ulster counties particularly the outcropping edge of the formation is characterized by a fringe of very large disconnected blocks occurring at various intervals. In some cases these blocks lie several hundred yards from the edge of the outcrop.

Goniatite

This is a local layer of limestone found near the base of the Hamilton group in Onondaga county. Westward in Genesee county at the village of Stafford it is called the Stafford limestone, and extends from there to Lake Erie.

Tully

This is the most southern limestone formation found in any part of New York except Orange and Westchester counties, and the limestone of those counties is largely dolomitic. It forms a layer about 10 feet thick at the top of the Hamilton group, and derives its name from its type occurrence at the village of Tully in Onondaga county. It is rather local in its extent, and does not occur in the eastern or western part of the state, extending only from Ontario to Madison. Few quarries have been opened in it, and it has only been extracted at times for purely local wants.

Excellent exposures of it occur however on the shores of both Cayuga and Seneca lakes, and the material could be easily quarried at these places.

Quaternary marls

These represent the only unconsolidated types of limestones found in New York. The deposits are usually found underlying swampy areas, specially in the central portion of the state between Syracuse and Rochester, being commonly underlain by clay, and overlain by muck.

The origin of these marls is a matter of much interest. While the marl is sometimes spoken of as "shell marl", at the same time the shells found in it form but a very small part of the whole, the greater portion being made up of granular carbonate of lime, and the probable cause of accumulation is by precipitation from calcareous waters, the snails being found in the marl because they frequent water carrying lime.

Central New York contains an abundance of calcareous rocks, and fragments from them are also found in the drift, so that there is abundant opportunity for the carbonated spring waters

to take carbonate of lime in solution. This is taken in solution in the form of a bicarbonate which, when exposed to the air, is very unstable, so that the lime is precipitated on the emergence of the water as a spring. Temperature may also effect the result, in that the lime carbonate is more insoluble as the temperature of the water rises. This cause has been argued for by I. C. Russell[1] as explaining the formation of marl deposits in Michigan. The marl, as it precipitates, settles not only on the bottom of the pond, but also on the grasses around the edge. This method of formation is observable in the kettle hole ponds in the terminal moraine near Cortland, New York. The effect of certain plants on the precipitation of carbonate of lime was referred to earlier in the report.

In this state the marl deposits are known to occur in the swampy areas near Warner and Jordan, Onondaga co.; in the valley from Wayland to Perkinsville, Steuben co.; Caledonia, Livingston co.; northwest of Canastota, Oneida co.; Cassadaga, Chautauqua co.; Cortland, Cortland co.; Clifton Springs, Ontario co.; Clarendon, Orleans co.; Bergen, Genesee co.; near Chittenango Falls, Madison co., etc. The associations and extent of these deposits vary, as does also the purity of the marl. In addition to these localities Beck also states that marl occurs at the following ones: 2 miles southeast of Lodi on branch of Cattaraugus creek, Cattaraugus co.; in Schuyler county, at Beaver Dams in town of Dix, near Horseheads and near Millport, Chemung co.; in Columbia co., 4 miles north of Kinderhook; in Dutchess co., towns of Rhinebeck, North East, Pine Plains, Stanford and Red Hook; Montgomery co., near Canajoharie, Fort Plain and Fonda; Niagara co., along Tonawanda creek, and in swamp 5 miles east of Lockport; Otsego county, in southern part of Cherry Valley township. Unless the area of marl is large, and this would be indicated by the size of the swampy tract, which it underlies, it

[1] Bul. 10. Geol. soc. Am. 1899.

does not pay to work it for any purpose requiring large quantities of raw material.

It seems curious that the sole application of this material which usually suggests itself is for the manufacture of Portland cement, and, while this is indeed an important application, still it is only worthy of consideration in the case of very large deposits, that is, those not less than 6 feet thick and of at least 100 acres area, while deposits smaller than this are open to nearly all the uses to which limestone can be put.

LIMESTONE OCCURRENCE BY COUNTIES[1]

In the following descriptions it has been attempted to give as far as possible the occurrence and extent of the different limestone formations in each county, together with their characters. As many analyses as possible have been collected, and a number of additional ones made for the report. Reports of an economic nature are rare, but a number of county and locality reports have been issued, the titles of papers and reports relating to the region being given. Where the report contains analyses, it is marked with an asterisk (*), and reports of an economic nature are also preceded by a dagger (†).

Albany county[2]

The only limestone formations in this county are the Lower Helderberg and the Corniferous. The former are specially conspicuous, as they form the Helderberg escarpment, which in this county reaches its greatest elevation.

Onondaga limestone. In Albany county, this formation appears as a terrace extending along the foot of the slopes formed by the Hamilton shales. In the northeastern face of Helderberg mountain the outcrop is narrow, but it widens to the westward, being a mile and a half at Thompsons lake, and after narrowing it again becomes 3 miles wide in the long slopes northwest of Berne. The formation in this county is a light bluish gray, tough, mas-

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1 *General articles on New York limestones*

Hall, James. County reports. (*see* Geol. 4th dist. N. Y.)

Merrill, F. J. H. Mineral resources of New York state. (*see* Bul. 15. N. Y. state mus.)

——— Guide to the study of the geological collections. (*see* Bul. 19. N. Y. state mus.)

Merrill, G. P. Stones for building and decoration.

Ries, H. Report on limestones of eastern New York and western New England. (*see* 17th an. rep't U. S. geol. sur., chapter on limestone)

Smock, J. C. Building stones in New York. (*see* Bul. 3 and 10. N. Y. state mus.)

2 Darton, N. H. Report on relations of Helderberg limestones in eastern New York. (*see* 13th rep't N. Y. state geol. 1893. p. 197–228)

——— Preliminary report on the geology of Albany co. (*see* 47th an. rep't N. Y. state mus. p. 425–55)

*† Nason, F. L. Economic geology of Albany county. (*see* 13th an. rep't N. Y. state geol. 1893. p. 263–87)

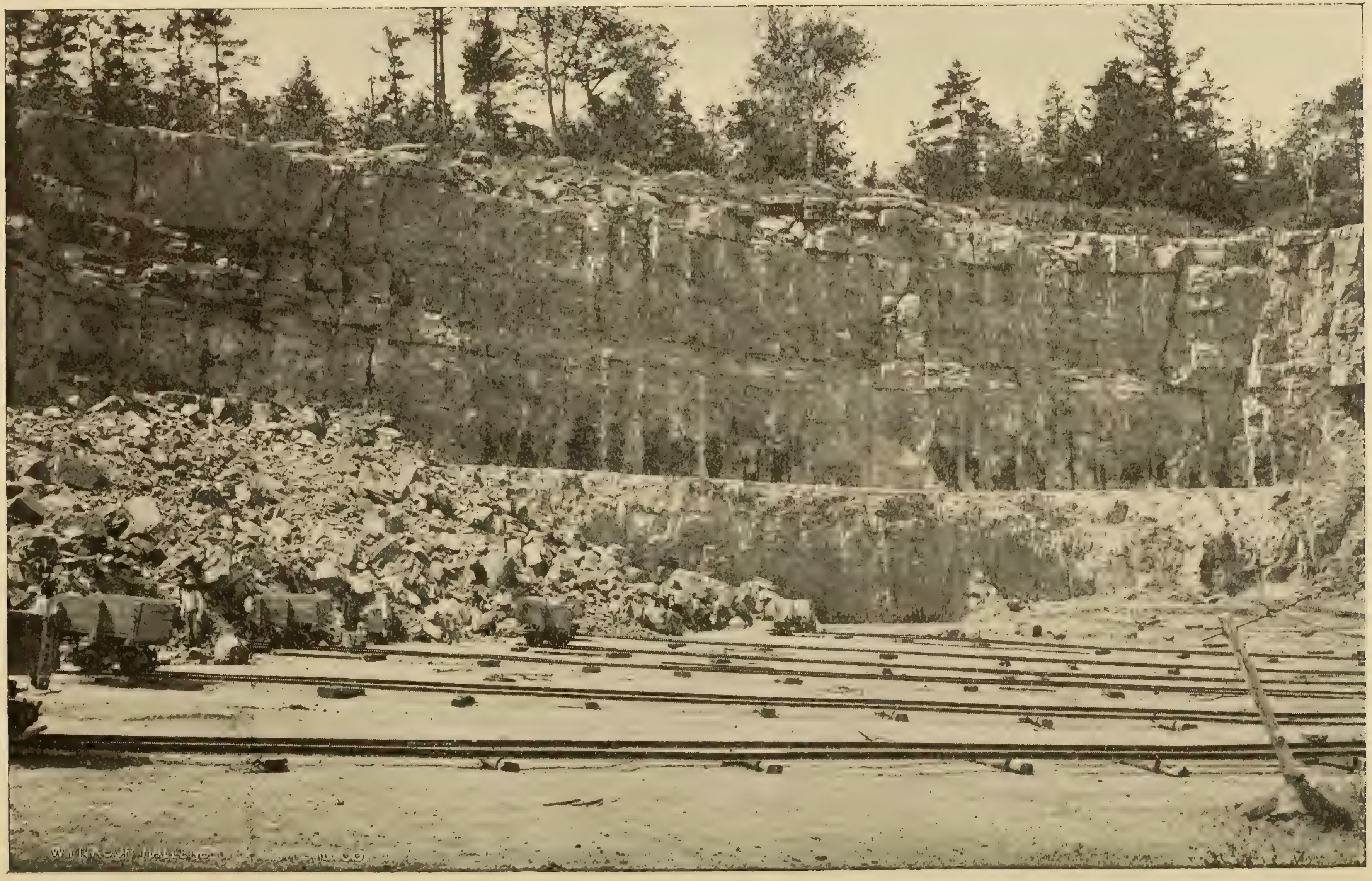
Mather, W. W. Geol. 1st dist. N. Y. 1843.

sive limestone, quite pure but containing lenses of chert, which are chiefly abundant in the lower beds. At times it disappears altogether, but this is not usual. One of the best ledges of Onondaga limestone is in the cliffs near Onisketháu creek at Clarksville.

Lower Helderberg limestone. This reaches a large development in Albany county and is divisible into several well marked members. The foremost of these is the Becraft, also known as the Scutella limestone. This rock is of light color, often crystalline and full of fossils. Its average thickness in Albany county is about 15 feet, and its composition may be inferred from an analysis given of the same bed occurring at Rondout, Ulster co., and Hudson, Columbia co. One exposure of it is in the creek bed south of Callanans Corners. Underlying the Becraft limestone is a series of different beds, of very impure, highly fossiliferous, shaly limestone of a gray and grayish brown color and probably too impure for any use except building or road-making. Their thickness averages 100 feet. Under these, however, comes the Pentamerus limestone, which is an important member of the Helderberg formation, whose outcrop is marked by lines of prominent cliffs. It is usually cracked, and its color is that of a red, bluish gray limestone, which is of a lighter color on the weathered surface. The beds are often cut by vertical joints and there may be occasional layers of shale. The Pentamerus limestone in Albany county has an average thickness of 65 feet. It is a well known formation and has been quarried for lime at numerous points throughout the state. One of the best exposures of this stone is at the Indian Ladder. Underlying the Pentamerus bed is a series of thin bedded, dark blue limestones, which generally crop out at the base of the Helderberg escarpment but are frequently hidden by the talus at the base of the cliff. These Tentaculite limestones are often of a shaly nature. Their thickness along the eastern face of Helderberg mountain according to Darton is about 30 feet. They are also exposed at the Indian Ladder and at South Bethlehem. An excellent section of both Pentamerus and the

Plate 28

To face p. 771



H. Ries, photo.

Quarry in Lower Helderberg limestone. South Bethlehem, Albany co.

Tentaculite bed, is seen in Callanan's quarry southwest of South Bethlehem (pl. 28), analyses of which are given below. Underlying the Tentaculite are the Waterlime beds, also exposed at Indian Ladder and in the floor of the quarry at South Bethlehem, and at both localities they are about four feet thick and represent impure magnesia limestones.[1]

The following analyses made for this report will indicate the character of limestones of the Helderberg series in Callanan's quarry at South Bethlehem.

Lower third of quarry

Silica	9.05
Ferric oxid	.99
Alumina	6.66
Lime carbonate	79.86
Magnesia carbonate	4.17
	100.73

Middle third

Silica	5.12
Alumina	1.45
Ferric oxid	.74
Lime carbonate	48.34
Magnesia carbonate	2.93
Carbon dioxid	41.22
	99.8

Upper third

Silica	11.16
Ferric oxid	1.15
Alumina	3.35
Lime carbonate	79.06
Magnesia carbonate	6.65
	101.37

[1] Darton, N. H. Geology of Albany county. (*see* 13th an. rep't N. Y. state geol. p. 423)

While the stone at South Bethlehem is used chiefly for road material, it could also be used in the manufacture of lime, or Portland cement, for it does not contain an excess of silica. Lying as the material does in close proximity to the clay deposits under the Quaternary terrace, it could be well utilized for cement manufacture.

Curiously enough, however, the limestones of Albany county are but little employed. A partial reason for this may be the great hight and steepness of the escarpment which they form, such conditions interfering somewhat with economic quarrying.

There are several quarries at Ravena and one at Aquetuck.

Cayuga county

Extending as it does in a north and south direction, Cayuga county includes several limestone-bearing formations, viz the Upper Helderberg, Lower Helderberg, Niagara, and Clinton.

The Upper Helderberg limestone extends across the county in a northeasterly direction from Union Springs to Auburn, and thence eastward. It is divisible into three members, viz the Onondaga, the Corniferous and the Seneca limestones. The Onondaga is some times spoken of as the gray Onondaga stone, and the last member as the Seneca bluestone.

At Union Springs there are three quarries, all of them in the Seneca bluestone, operated by J. Shalebo, B. P. Smith and G. P. Wood. The stone is used chiefly for building purposes, but some of it runs quite high in carbonate of lime. The following[1] represents the average composition of the largest quarry which is east of the town, and about one mile from the lake. In the quarries on the southern edge of the town, the stone is rather free from impurities in the lower layers, but the upper ones often show a transition to the Marcellus, and in one or two sections a layer of the Goniatite limestone is observable. Plate 29 shows the Corniferous limestone quarry at Union Springs.

At Auburn both the Corniferous and the Onondaga members are quarried. The latter is exposed in some of the smaller quar-

[1] This analysis does not occur in the manuscript. ED.

To face p. 772

H. Ries, photo.

Quarries in Corniferous limestone at Union Springs

Plate 30

To face p. 773

H. Ries, photo.

General view Montezuma marshes

ries, and the layers are often highly loaded with chert, but in the large quarries of L. S. Goodrich & Son on Cottage street the gray Onondaga member is quarried. The layers here are free from chert, but the stone is a hard, dense fine grained rock, which is used for building and also lime-making. It burns to a lumpy but not very white lime, that of the best quality coming from two layers each about 5 feet thick in the upper portion of the quarry.

The following analysis represents the run of the quarry

Silica	13.5
Alumina	3.7
Ferric oxid	1.5
Lime carbonate	61.66
Magnesium carbonate	19.44
Insoluble	17.5
Total	99.8

The Lower Helderberg limestone also crosses the county in a belt parallel to the Upper Helderberg. It is first exposed at Union Springs on the hill about one and a half miles to the north of the town, on the Lowery farm, where it underlies the Oriskany sandstone. At this point the layers are very shaly, and the purer ones would have to be sought farther toward the northern edge of the outcropping beds of the formation. The width of the belt is from two to three miles. So far as the writer is aware, it is not quarried within the limits of the county. This may be partly due to the fact that there is a heavy covering of drift in many places that would easily tend to cover it up.

At Montezuma the works of the Duryea Portland cement co. were built to use the marl underlying Montezuma swamps, but, since their destruction by fire several years ago, no attempts have been made to revive the industry at that point. The Montezuma marshes (pl. 30), underlie an extensive tract, and marl is said to

occur under them at several points. Borings were made by the writer across the swamp at a point two miles north of Union Springs but no marl was found.

Chautauqua county[1]

The only lime deposits are a few scattered beds of marl. The most important is on Cassadaga lake, and a Portland cement plant was erected at this point several years ago, but is now closed down.

Clinton county[2]

Calciferous. Rocks of this age are abundantly exposed in Champlain, Beekmantown and Peru townships. The rocks are usually blue gray, massive, sandy dolomites. Owing to their sandiness they have little value for the manufacture of lime or cement.

The Trenton and Chazy limestones occupy a broad belt which extends along the western side of Lake Champlain from Peru northward to the Canadian boundary, the western edge passing close to West Chazy, Chazy and Coopersville.

Chazy limestone. This limestone is well exposed at the village of Chazy as well as in other parts of Chazy township, specially just north of Plattsburg, and on Bluff point two miles south of the latter place, whence it extends south into Peru, where the lower portion of the formation is well shown. The aggregate thickness of the Chazy limestone at Chazy village is 740 feet, while at Valcour it is said to be 890 feet. The rock is quarried at a number of points for obtaining marble, rough building stone or stone for lime.

Black river limestone. The rocks of this group occur as massive dark colored beds, but are well exposed at numerous points in

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1 Hall, James. (*see* Geol. 4th dist. N. Y. p. 493)

2 Cushing, H. P. Geology of Clinton county. (*see* 13th an. rep't N. Y. state geol. p. 513)

——— Faults of Chazy township, Clinton co. (*see* Bul. geol. soc. Am. 6: 285)

——— Geology of Rand Hill and vicinity, Clinton county. (*see* 19th an. rep't N. Y. state geol. p. 39)

Emmons, Ebenezer. Geol. 2d dist. N. Y. 1842.

Plate 31

To face p. 775

H. Ries, photo.

Lime quarry at Chazy

Chazy overlying the Chazy limestone, but outside of the village and in Chazy township it is not very well exposed. According to Cushing it has a thickness of 30 to 50 feet and is a brittle black limestone with a conchoidal fracture.

Trenton limestone. This is also well exposed in the town of Chazy and in addition in the town of Plattsburg. Cushing states that in the bed of the river just east of the Chazy village 150 feet is exposed lying on the Black river limestone, while on Crab island about 200 feet of it can be seen. The lower portion of the Trenton limestone generally exhibits beds of a slaty character and is probably of insufficient purity for any chemical use except that of making common lime and for fertilizing purposes or perhaps Portland cement. Also in northeastern Plattsburg township, and extending into southeastern Beekmantown, the rocks according to Cushing form a series of black slaty limestones which are excellently exposed on Cumberland head.[1]

The Chazy limestone is of high purity and makes a most excellent quality of lime.

The following is an analysis made by D. H. Newland.

Silica	.72
Alumina and ferric oxid	.39
Lime carbonate	96.24
Magnesium carbonate	3.02
	100.37

The quarries are near the railroad and the product can be easily shipped.

There are several lime quarries in operation in the village of Chazy, the one being on the eastern edge of the town and another about a mile out (pl. 31). Recently a third quarry has been opened on the southeastern edge of the village, and three limekilns erected. It affords an excellent location for

[1] Cushing, H. P. Geology of Clinton county. (*see* 13th an. rep't N. Y. state geol. p. 513)

cement manufacture, as the lowlands which the limestone ledges border are underlain by clay. The Chazy limestone bears a high reputation not only for the manufacture of lime, but also as a furnace flux.

The following is an analysis of the burned stone used for flux at Troy, E. Touceda, analyst.

Lime oxid	97.48
Magnesium oxid	1.4
Alumina	.14
Ferric oxid	.12
Silica	.79
Total	99.53

Columbia county[1]

The limestones in the eastern part of the county are of little importance on account of their impure nature, but on Becraft mountain east of Hudson the stone has been extensively quarried for a number of years to supply the furnaces at Troy with flux. Two types of stone are found here, viz the Becraft or Scutella limestone, and the blue Pentamerus rock.

The Pentamerus limestone is quarried on the cemetery property at the northeastern edge of the town (pl. 32). It is well exposed in a face about 100 feet long and 25 feet high. With the exception of the upper 6 feet the layers are quite free from chert. The rock shows occasional cavities with calcite crystals and at times quartz, but otherwise probably does not run over 3% or 4% in silica. While the stone has hitherto been used only for road material, still it affords a source of limestone for the manufacture of Portland cement, the necessary clay being obtainable from the terraces north of the city.

The most abundant material is the Becraft limestone already referred to. Extending along the top of the ridge are a series of

[1] Bishop, I. P. On certain fossiliferous limestones of Columbia county N. Y. and their relations to the Hudson river shales and the Taconic system. (*see* Am. jour. sci. 1886. 32: 438).
Mather, W. W. Geol. 1st dist. N. Y. 1843.

H. Ries, photo.

Quarry in Pentamerus limestone, Hudson, Columbia co.

Plate 33

To face p. 777

H. Ries, photo.

Shute & Rightmyer's quarry in Becraft limestone near Hudson

openings, which were originally opened as marble quarries, but found unsuitable and subsequently worked for dimension stone and flux, these operations continuing to the present.

The limestone is a coarsely crystalline, fossiliferous rock, of moderately pure and quite uniform character. The stone has to be hauled 600 to 1000 feet to the railroad siding, thus permitting easy shipment.

The following analyses, no. 1 by T. Egleston and no. 2 by the chemist of the Burden iron works at Troy illustrate the character of the stone.

	1	2
Lime	51.4	......
Lime carbonate	......	91.7..
Carbon dioxid	41.191	......
Magnesium carbonate	......	3.51
Magnesia	2.233	......
Alumina	.635	1.01
Ferric oxid	1.819	.55
Silica	1.842	1.89
Sulfur dioxid	.145	.049
Phosphorus	.149	.022
Water	.271	......
	99.685	98.731

While Mr Jones still owns some of the quarries, the majority are said to be owned by Shute & Rightmyer (pl. 33).

Dutchess county[1]

The limestones in the eastern part of the county are a continuation of those found in Westchester county and follow the line of the Harlem river railroad, while those found in the central and

[1] Dwight, W. B. On the recent explorations in the Wappinger valley limestones of Dutchess co., N. Y. (*see* Am. jour. sci. 1879. 17: 399)

—— Recent investigations and palaeontological discoveries in the Wappinger limestone of Dutchess and neighboring counties, New York state. (*see* Proc. Am. ass'n adv. sci. 31: 384; *also* Am. jour. sci. 1884. 27: 249)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

western portions of the county are a continuation of the Orange county Cambro-Silurian limestone belts. The former are metamorphosed limestones and partake of the nature of marble, being highly crystalline, while the latter are not.

The eastern belt. While there are outcrops of the limestone at a number of points in the valley followed by the Harlem railroad, only two large openings have been made. These are at Dover Plains and South Dover.

At Dover Plains, G. & J. H. Ketcham have operated a quarry along the highroad one half mile southeast of the town. The rock is a soft, fine grained dolomite of gray or white color. The opening is about 200 feet long, 20 to 30 feet wide and 10 feet deep. No analysis was made of the stone but several samples were examined to determine their insoluble matter, which ran from 2 to 3%.

The South Dover marble co. has a large quarry (pl. 34) on the hill 2½ miles northeast of the station. The rock is a fine grained, white dolomite and has hitherto been used only for structural purposes. It has to be hauled to the railway. In appearance it is very free from impurities. The following analysis of the rock was furnished by the superintendent of the company.

Silica	.7
Ferric oxid	.25
Alumina	.37
Lime	30.63
Magnesia	20.25
Soda	.12
Potash	.46

The stone is brought down to the railroad over a private trolley line.

The limestones in the western part of the county are usually a hard, fine grained bluish gray rock, containing less magnesia than the whiter phases to the southeast and east. It has been used for lime but on the whole is so silicious that the resulting lime would be lean.

Plate 34

To face p. 778

H. Ries, photo.

Quarry of South Dover marble co. South Dover

To face p. 779

H. Ries, photo.

Quarries at Clinton Point, north of New Hamburg

Since dolomitic limestones tend rather to disintegrate than to decompose, their outcrops are often surrounded by a white granular sand, and are easily discernible for some distance. The western belt has been quarried in large quantities at Clinton point (pl. 35), 2 miles north of New Hamburg. Its silicious nature restricts its use to road metal.

An analysis of this stone gave:

Lime	29.07
Magnesia	16.29
Carbonic acid	40.76
Alumina	2.33
Ferric oxid	.47
Silica	10.17
	99.09

Erie county [1]

The only limestone formations represented in this county are the hydraulic or waterlime, the Onondaga and the Corniferous.

According to Bishop, "the northern edge of the Corniferous limestone, together with the Onondaga limestone and the upper part of the hydraulic limestone, forms a well defined escarpment, which runs in a general southwest direction on the Genesee county line to Buffalo. Most of this distance the escarpment is nearly parallel to the Bloomingdale and Williamsville road. The hydraulic limestone is generally visible at the base of the escarpment, where it forms a layer of variable thickness in the face of the cliff. Sometimes it forms a terrace from a few feet to 200 yards in width which runs parallel to the escarpment. This is specially well marked between the Williamsville and Buffalo

[1]† Bishop, I. P. Structural and economic geology of Erie county. (*see* 15th an. rep't N. Y. state geol. p. 305)
Hall, James. Geol. 4th dist. N. Y. p. 469.
Pohlman, J. Cement rock and gypsum deposits in Buffalo. (*see* Trans. Am. inst. min. eng. Oct. 1888)

city line. The Onondaga limestone in Erie county forms a thin band between the hydraulic limestone and the overlying Corniferous limestone. It varies in color from blue gray to a light gray, and also varies in thickness, reaching its maximum of 35 feet in Fogelsonger's quarry at Williamsville. It is the same thickness 2 miles farther on but then begins to thin out rapidly. The formation in Erie county, instead of being of one continuous bed, is really a series of lenticular masses occurring at the same horizon. The Corniferous limestone in Erie county forms somewhat of an escarpment, as already mentioned. The rock outcrops are not as a rule very extensive, but good ones occur a few miles below Millgrove near a dam across Endicott creek, and again in the bed of the same stream for 3 miles below Wilhelm, and also near the same place. Again this limestone is found in Gage creek at Kieffer's quarry near the transit road about a mile west of Lancaster.

Hydraulic limestone. This extends through Williamsville, Clarence and Akron. Along the whole line of its outcrop it has been quarried at numerous places but generally only for building purposes. The section at the works of the Buffalo cement co. gives the following relations of the three limestones: flint and limestone, Corniferous, 3 to 9 feet; Onondaga lime, 5 feet 8 inches; loose friable limestone, 6 inches; gypsum crystal, 6 inches; hydraulic limestone, porous, known as bullhead, 7 feet; cement rock used for burning, 3 feet 8 inches; impure hydraulic lime at bottom (pl. 36).

The bullhead stratum furnishes the greater part of the waterlime used for building purposes.

Onondaga limestone. One or two of the lenticular masses already mentioned occur near Williamsville in the quarry of Fogelsonger & Young. It is highly fossiliferous and quite pure, as shown by the following analysis made by H. Carlson and quoted by Bishop.[1]

[1] Geology of Erie county. (*see* 15th an. rep't N. Y. state geol. p. 331)

Plate 36

To face p. 780

I. P. Bishop, photo.

Quarry of the Buffalo cement co., Buffalo, Erie co.

Plate 37

To face p. 781

I. P. Bishop, photo.

Road metal and paving block quarry of the Barber asphalt co. Near Humboldt parkway, Buffalo, Erie co. Corniferous limestone

Lime carbonate	96.54
Magnesium carbonate	1
Iron and alumina oxid	.84
Silica	1.17
Sulfur	.101
Phosphorus	.017
	98.668

Some of the rock is used for smelting purposes, and the waste is burned for lime.

Corniferous limestone. The chief use for this is also for building operations. The largest quarry in Erie county is that of the Buffalo cement works, but there are numerous other smaller ones. The limestone, while making a good building material on account of its hardness, is very cherty in places, and therefore for any chemical or similar work would probably have to be hand picked. The limestone is usually thickly bedded (pl. 37).

Essex county[1]

The pre-Cambrian rocks of Essex county often include a series of crystalline limestones, which are not infrequently speckled with grains of pyroxene and other dark silicates. Occasionally these silicates are segregated into bunches, thus leaving the rest of the rock comparatively free from impurities. At times the limestone beds attain a thickness of 50 feet to 100 feet, as at Port Henry, where they have been quarried for flux. The quarry has not been operated for several years.

[1] White, T. G. Geology of Essex and Willsboro townships, Essex co., N. Y. (*see* Trans. N. Y. acad. sci. 13: 214)

Merrill, G. P. On serpentinous rocks from Essex county. (*see* Proc. U. S. nat. mus. 12: 595)

Brainard, E. The Chazy formation in the Champlain valley. (*see* Bul. 2. Geol. soc. Am. p. 293)

——— & Seely, H. M. The Calciferous formation in the Champlain valley. (*see* Bul. 3. Am. mus. nat. hist. p. 1; also Bul. 1. Geol. soc. Am. p. 50)

Kemp, J. F. Preliminary report on geology of Essex county. (*see* 13th an. rep't N. Y. state geol. p. 625)

——— Geol. of Moriah and Westport townships, Essex co., N. Y. (*see* Bul. 14. N. Y. state mus.)

Emmons, Ebenezer. Geol. 2d dist. 1842.

Three distinct areas of Chazy and Trenton limestones occur in this county. The first forms Willsboro point and extends southward as far as Whallonsburg. A second area begins at Westport and extends southward to the town of that name. A third is on Larrabees point.

The Black river limestone member of the Trenton is usually heavy bedded, very tough and compact. The rock has been quarried on Crown point.

The Trenton proper, also exposed on Crown point, is 150 feet thick, but is usually thin bedded, showing alternations of limestone and shale layers. The Trenton has been used at several places for making lime, but no definite statement can be made concerning the purity of any given beds, as they are variable. At times the rock is quite low in silica. Large quarries have been opened on Willsboro point (pl. 38), and in the town of Essex, and the stone from the former was shipped to New York city.

A partial analysis of the Chazy limestone on Willsboro point, furnished the writer by Prof. J. F. Kemp, showed:

Lime	51
Magnesia	1
Silica	2.43

The following represent the average composition of 1) the upper 10 feet and 2) the lower 10 feet of the quarry from analyses made of samples collected by the writer.

	1	2
Silica	4.4	4.6
Alumina	7.1	4.1
Ferric oxid	3.5	1.9
Lime carbonate	79.2	87.7
Magnesium carbonate	4.2	.98
Insoluble	15	12.6
Water	....	2

The following additional ones are given by T. G. White.[1]

1 Lower beds of quarry on Willsboro point.

[1]† Geology of Essex and Willsboro townships, Essex co., N. Y. (*see* Trans. N. Y. acad. sci. 13: 214–31)

To face p. 782

H. Ries, photo.

Clark's quarry on Willsboro point

2 Same as 1 with carbonates calculated.

3 An analysis of Chazy limestone quoted from Boynton,[1] and said to be from Willsboro.

	1	2	3
SiO_2	2.43	2.43	21.39
CaO	51	.....	.....
$CaCO_3$	....	91.1	70.31
Al_2O_3, Fe_2O_3	.41	.41	3.61
MgO	1	2.1	1.09
Na_2O	....	.....	tr.
K_2O	....	.....	.8
Cl	....	.....	.31
H_2SO_4	....	.....	.69
H_3PO_4	....	.....	.2
Organic matter	....	.....	1.4
	54.84	96.04	99.8

Fulton county[2]

The Calciferous and Trenton limestones form a crescent shaped belt extending from Crum creek, northwest of St Johnsville, through Garoga, Johnstown, Gloversville and Mayfield up to Northville. A second belt extends from Northville to the southern boundary and has a width of about 6 miles.

Quarries are in operation at Cranberry creek and Mayfield.

Genesee county[3]

A very small triangular area of Niagara limestone occurs in the northeastern corner of the county and a second very thin strip along the northern edge.

The Helderberg, on the contrary, extends through the central part of Genesee county, passing through Batavia, Stafford, East

1 Trans. N. Y. state agric. soc. 1852. 12: 801.

2 Darton, N. H. Geology of the Mohawk valley in Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 47th an. rep't N. Y. state mus. p. 601)

—— Preliminary description of the faulted region of Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 14th an. rep't N. Y. state geol. p. 33)

Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

3 Hall, James. (*see* Geol. 4th dist. N. Y. p. 464)

Pembroke and Corfu, and Leroy. A quarry is operated by J. Merrill near Batavia, but the greater number of quarries lie in the Corniferous at Leroy, where much stone is extracted. The Leroy rock is dark colored, medium to fine grained and is used both for lime and furnace flux. The principal quarry at Leroy is that of Morris & Strobel, but most of the quarries are at Lime Rock near Leroy. The quarries are mostly small, and many of the layers cherty, but those free from chert (and they are at times as much as 3 feet thick) are of very good quality. The following analysis of Leroy limestone from Howells quarry was kindly furnished by the Tonawanda Iron & Steel co.

Lime carbonate	92.46
Magnesia carbonate	1.86
Silica	5
Alumina	.6
	99.92

A second analysis made of a sample collected by the writer from Morris & Strobel's quarry yielded:

Silica	5.96
Alumina	3.16
Ferric oxid	1.34
Lime	49.07
Magnesia	1.44
Carbon dioxid	40.13
	101.1

The third analysis shows composition of lime, furnished by W. S. Brown at Leroy.

Lime	94
Magnesia	1.4
Iron oxid	1.1
Silica	3.2
Alumina	.3
	100

Overlying the gypsum beds which occur in the town of Leroy there is occasionally found a drab limestone resembling cement rock in appearance. The following analysis was made of a sample from the land of Mr Howell near Leroy, D. H. Newland, analyst.

Silica	4.02
Alumina	1.48
Ferric oxid	1.07
Lime carbonate	57.87
Magnesium carbonate	35.09
	99 53

This composition would not indicate that the material had very great hydraulic properties, as it runs low in clay.

According to Hall[1] the hydraulic limestone is exposed on Allens creek, 2 miles north of Leroy, and also at Morganville.

Genesee county contains several swamps underlain by marl.

One extensive deposit occurs along the line of the New York Central railroad about a mile west of Bergen, on the land of P. Snyder, and G. E. Parish and also on what is known as the Doran farm. Attempts have been made to organize a Portland cement company to work the material. The following analysis made by J. A. Miller, of Niagara university, was furnished.

Silica	.49
Alumina and ferric oxid	.35
Lime sulfate	3.48
Lime carbonate	94.12
Magnesia	tr.
Undetermined	1.56
	100

Marl is also said to underlie the Beaver Meadows at Leroy.

[1] Geol. 4th dist. N. Y. 1843. p. 465.

Greene county[1]

The only limestone formations in the county are those of the Lower Helderberg and Upper Helderberg, which extend across the eastern part of the county from its northern to its southern border, the two belts being separated by the Oriskany sandstone.

The Onondaga is usually represented by its cherty member, the Corniferous, and is of little use except for building purposes and road material, but the Lower Helderberg supplies an abundance of lime rock, which could be employed in several directions. At the northern boundary the Lower Helderberg limestone ridge is probably 2 miles back from the river, the shore lines of the Quaternary terrace abutting against it. In this vicinity it is quarried near New Baltimore, by W. Fuller's Sons. At Catskill, however, the ridge approaches close to the Hudson, and is easily available for shipment. Both the Scutella and also the underlying members are exposed in the ridge, which closely follows the river from Catskill southward to Saugerties, and, while they have been much used for building, other uses have remained in the background.

Recently the possibility of combining the Helderberg limestone with the nearby Quaternary clays for the manufacture of Portland cement has been recognized, and several factories are in contemplation, while one large works is nearly completed at Smiths Landing.

Where a selection of certain layers is to be observed, the dip of the beds has to be considered, for in this ridge it is quite variable, owing to the folding which the region has been subjected to.

The Becraft limestone forms the most massive member of the Lower Helderberg in Greene county. It is similar in its characters to that found on the eastern side of the river near Hudson, and is underlain by the Tentaculite and Pentamerus. West of Catskill it has been extensively quarried by George Holdredge

[1] Mather, W. W. Geol. 1st dist. N. Y. 1843.

Plate 39

To face p. 787

H. Ries, photo.

Becraft limestone in G. M. Holdredge's quarry, west of Catskill

Plate 40

To face p. 787

N. H. Darton, photo.

Calciferous sandrock, East Canada creek, Herkimer co. 2 miles above its mouth

(pl. 39). The rock shows the usual coarse grained, fossiliferous character, and the beds lie nearly horizontal with a slight dip to the west. The stone is quite homogenous, and a sample analyzed by the writer and representing the average of the quarry gave:

Silica	2.75
Alumina	1.5
Ferric oxid	1.6
Lime	53.1
Carbonic acid	42.1
	101.05

The quarries lie about 1 mile from the river and the West Shore railroad.

Herkimer county[1]

The Calciferous sandrock occurs in the county around Little Falls and is well exposed in several quarries in the town and also on the south side of the river. It is generally a light bluish gray, fine grained, massively bedded sandy limestone whose weathered surfaces are generally dirty buff. The following analysis will illustrate well its silicious and magnesian character.

Silica	10.5
Alumina	3.03
Ferric oxid	.77
Lime carbonate	47.96
Magnesium carbonate	36.89
	99.15

[1] Darton, N. H. Geology of Mohawk valley in Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 47th an. rep't N. Y. state mus. p. 603)
—— Preliminary description of the faulted region of Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 14th an. rep't N. Y. state geol. p. 33)
White, T. G. Report on the relations of the Ordovician and Eo-Silurian rocks, in portions of Herkimer, Oneida and Lewis counties. (*see* 51st an. rep't N. Y. state mus. 1: r21)
Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

The other limestone formations found in the county are of much greater importance. The Helderberg limestones extend across the southern edge of the county as a belt several miles wide, whose northern limit passes through the towns of Jordanville, Columbia, Cedarville and Cedar Lake. They have been quarried at several places, Columbia among them, for lime burning, but their distance from the railroad is a serious objection.

The Tentaculite limestone is utilized at Columbia south of Little Falls for the manufacture of lime, and a sample from A. Manning's quarry showed the following composition.

Silica	4.91
Ferric oxid	.53
Alumina	.48
Lime	51.82
Magnesia	1.16
Carbon dioxid	41.9
	100.8

The same quarry shows two thin layers of waterlime.

The group of Trenton limestones is of some importance in Herkimer county, but only the Birdseye and Trenton members are present.

Around Little Falls the Trenton is not over 4 feet thick according to Darton, but at Ingham Mills the rock is well exposed in the lime quarry of Sherman Butler (pl. 41), where nearly 15 feet of good stone can be seen. The better stone is bluish, fine grained and massive, but in the upper part of the quarry it passes into the Utica slate. The following analyses represent its composition, no. 1 being the lower massive rock and no. 2 the average of the quarry face.

	1	2
Silica	6.7	8.45
Alumina	3.03	2.72

H. Ries, photo.

Butler's quarry, Ingham Mills, showing Birdseye limestcne passing upward into Utica shale

Ferric oxid	.21	.84
Lime carbonate	89.15	84.6
Magnesium carbonate	tr.	3.42
	99.09	100.03

From Ingham Mills the Trenton limestone passes northwestward past Salisbury and Norway to the edge of the county, where it forms a belt whose width extends from Poland to Grant. A spur also extends from Poland southeast to Middleville, and it is quarried at Newport by G. S. Higgins, J. Dunn, N. Morey, W. W. Mosher, G. H. O'Connor, C. Smith, and D. Tuomey.

Jefferson county [1]

Probably one half the county is underlain by limestones, mostly of Trenton age, while additional small areas of pre-Cambrian age are known to occur. The Trenton limestone occupies a more or less triangular area, the towns of Clayton, Carthage, and Mannsville being approximately in the corners. The area is traversed by the several branches of the Rome, Watertown and Ogdensburg railroad.

The Calciferous sandrock, though known to occur in Jefferson county, is usually covered by the Birdseye. According to Emmons[2] the Calciferous is exposed 4 miles south of Theresa falls on the Watertown road, also 1½ miles east of French creek and near Depauville.

The Birdseye extends across the county from east to west, having a breadth of about 10 miles. Its northern edge passes through Depauville, and a point 2 miles south of Evans Mills on Indian river, thence to the great bend on Black river, and then to a point 2 miles southwest of Carthage. The Birdseye is thick bedded, and compact and usually of considerable purity. The total thickness of this member is not over 40 feet in Jefferson county.

1 Emmons, Ebenezer. Geol. 2d dist. N. Y. 1842. p. 368.
2 Geol. 2d dist. N. Y. 1842. p. 380.

The Black river limestone rests on the Birdseye and derives its name from its occurrence along the Black river. It is very thick bedded, but at Watertown seems to be formed of lumpy masses. Its color is black, and not over 7 feet thick, being known to quarrymen as the 7-foot tier.

The Trenton limestone is divisible into two members, viz, a compact, black stone, and a gray, crystalline one. The former is sometimes evenly bedded, with masses of interbedded slate; while the gray is often more massive. The Trenton member first appears as a bluff at Watertown, and southward from there forms a series of terraced hills. Its total thickness is about 300 feet. Its boundaries extend from Champlain northwest to the Black river at a point 4 miles east of Watertown, thence to Henderson and then south to Ellisburg. The southern boundary passes nearly northeast from Mannsville in the direction of Adams, Whitesville and Tylerville. While the chief use of the different Trenton members has been for building, still it would make an excellent lime. It is quarried at Cape Vincent, Chaumont, Clayton, Pamelia, Redwood, Threemile Bay, Theresa, and Watertown.

Lewis county[1]

The Trenton limestone extends across the county in a northwesterly direction and follows the line of the Rome, Watertown and Ogdensburg railroad. It has been quarried at several localities, among them Leyden, Lowville and Collinsville.

The Birdseye member is well exposed along the road from Port Leyden to Leyden, 1½ miles south of the former locality on the land of Peter Snyder. The rock here is a fine grained, brittle, light gray stone, full of calcite eyes. An analysis of it made by D. H. Newland gave:

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[1] White, T. G. Report on relations of the Ordovician and Eo-Silurian rocks in portions of Herkimer, Oneida and Lewis counties. (*see* 51st an. rep't N. Y. state mus. 1: r21)
Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

Silica	6.5
Alumina	1.67
Ferric oxid	.76
Lime carbonate	88.44
Magnesium carbonate	2.68
	100.05

This same stone outcrops for some distance along the railroad track south of this point.

South of Leyden and below the railroad level is a large quarry of black, finely crystalline limestone on the land of Mrs Christy. The stone has thus far been used for building purposes only. It probably represents the Trenton proper. It is of greater purity, however, as shown by the following analysis.

Silica	1.44
Alumina, Ferric oxid	.83
Lime carbonate	97.36
Magnesium carbonate	1.04
	100.67

The Trenton limestone has been quarried for lime burning at Collinsville 3 miles north of Port Leyden. The rock here as exposed in Roberts's lime quarry is a coarse grained, gray stone, in thin layers 2 to 8 inches thick and often containing irregular partings of bituminous shale. They so predominate at times as to give the rock a shaly character, and such portions are discarded. The stone makes a white lime, as might be expected from its low silica and iron percentage. The composition of the stone as analyzed by Mr Newland is as follows:

Silica	3.09
Alumina	1.15
Ferric oxid	.49

Lime carbonate	94.11
Magnesium carbonate	1.63
	100.47

At Lowville the Trenton limestone is exposed in J. Waters's quarry, $1\frac{1}{2}$ miles north of the town and along the Rome, Watertown and Ogdensburg railroad. The upper layers are black limestone with calcite spots, while the lower ones which are chiefly used are light gray, finely crystalline stone.

The composition of Mr Waters's limestone is:

Silica	3.96
Alumina, Ferric oxid	1.7
Lime carbonate	91.27
Magnesium carbonate	3.78
	100.71

Livingston county[1]

The Helderberg rocks outcrop in the northern part of the county, but quarries are few. The Corniferous limestone has been quarried in the southeast corner of Caledonia township. The marls are perhaps of more importance than the limestones. The Wheatland deposit (mentioned under Monroe county) extends into Livingston, and another is known 1 mile east of Caledonia.

One good deposit has been opened up on the property of J. Simpson, 3 miles east of Mumford (pl. 42). The marl runs about 6 feet in thickness, and the upper, 20 inches to 2 feet, contains more clay than the lower. At the junction between the two are numerous shells. Below the 6 feet of marl there is said to be 6 feet of blue clay. Mr Simpson's marl has been shipped to Buffalo for the manufacture of carbon dioxid. The following is an analysis of the upper half.

[1] Hall, James. Geol. 4th dist. N. Y. p. 459.

To face p. 792

H. Ries, photo.

Marl pit on J. Simpson's property near Caledonia

Plate 43

To face p. 793

H. Ries, photo.

Douglas ditch near Oniontown, showing marl bed underlying soil

Silica	1.1
Alumina	1.5
Ferric oxid	
Lime carbonate	97.4
Magnesium carbonate	tr
Insoluble	.026

It is reported that a Portland cement plant will be erected at this locality.

Madison county[1]

Madison county has limestones of Niagara and Lower Helderberg age and Quaternary marls.

The Niagara limestone crosses the county as a narrow belt from Bridgeport to near Oneida Castle, the former locality being situated on its northern edge. Owing to the heavy covering of drift, and the swampy character of the region in many places, outcrops are scarce. It is, however, quarried at Oneida by Mrs C. L. Faulkner and about $1\frac{1}{4}$ miles northeast of Canastota by Stout Bros. on the South Bay road.

The outcrops of Lower Helderberg limestone extend through the central part of the county in a rather sinuous belt, passing south of Chittenango and through Chittenango Falls, Perryville, Blakeslee, Cottons, Siloam, Stockbridge and Munnsville. Material for lime-making is quarried at a number of these points.

Cowaselon swamp is an extensive swampy area extending from the northern edge of Canastota westward to the county boundary. Owing to the richness of its soil, extensive ditches have been dug for draining the area, and in the excavation of these much marl has been exposed. One of the best sections is along the Douglas ditch and its feeders east and west of Oniontown, 3 miles north of west from Canastota. Here at least 6 feet of marl is exposed in the sides and bottom of this ditch. On F. Pennock's land west of Oniontown the marl is said to be 30 feet thick. The marl is covered by 3 feet to 4 feet of sand and

[1] Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

organic matter. Whether or not clay underlies the marl is not known.

Marl also occurs on the land of J. C. Austin, 2 miles north of Canastota, and about a foot of it is exposed in the ditch in J. D. Conley's land, 1 mile north of town (pl. 43, 44). So far as known none of this marl has thus far been utilized. The following is an analysis of the material.

Silica	2.1
Alumina Ferric oxid	1.93
Lime carbonate	87.1
Magnesium carbonate	2.31
Insoluble and organic matter	11

Another deposit of marl is found south of Chittenango Falls.

Monroe county[1]

The Niagara is the most prominent and extensive limestone in the county, though Clinton, and Onondaga are also known. Quaternary marl is likewise found.

The Niagara limestone extends across the county as a belt several miles wide, its northern edge passing through the towns of Penfield, Brighton, Ogden, Gates and Sweden. The upper magnesian member generally forms the outcrops, and the weathered surface of the rock has a peculiar granular and spongy appearance. The upper member, or Guelph limestone, is a grayish brown, finely crystalline limestone containing numerous small cavities. The rock is very low in silica and has a large amount of magnesia, making it well adapted for refractory linings in furnaces. The lower beds of Niagara limestone are hard, compact and generally highly silicious in Monroe county. The Niagara shale underlies the Niagara limestone, and the transitional beds between the two sometimes furnish a natural cement rock. Beds of this nature outcrop at Shelby falls in the town of Barre.

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[1] Hall, James. Geol. 4th dist. N. Y. p. 422.

Plate 44

To face p. 794

H. Ries, photo.

View across Cowaselon swamp, looking northwest

H. Ries, photo. General view of quarries on Pike property, Rochester

Plate 46

To face p. 795

H. Ries, photo.

Section in quarry corner; Snyder and Frost avenues, Rochester

Plate 47

To face p. 795

H. Ries, photo.

Quarry of Whitmore, Rauber & Vicinus, W. Goodman street, Rochester

The lower member of the Niagara limestone is used only for building and road material, but the upper member, or Guelph, is extensively sought for lime-making.

In quarrying it for this purpose the massive layers are preferred to the cellular ones, as it is claimed that they yield a better grade of lime. Owing to its magnesian character, the lime is not very fat and consequently does not develop as much heat in slaking as one made from a pure stone.

A group of quarries is located at Snyder street and Frost avenue, Rochester, and known as the Pike quarries (pl. 45). The section exposed in the Guelph rock is about 18 feet thick, and the upper 5 feet, which is free from cavities, is said to make the best lime. Near the bottom is a 4 foot layer called by the quarrymen the "Hogback", which, it is claimed, does not make a good lime. Some stone is being drawn from this quarry to Mrs J. Hurd's limekiln at Jefferson and Seward avenues. The lime from this kiln is used chiefly for mortar but is also utilized to some extent by the glass works at Rochester.

The lower member of the Niagara limestone, which is not fit for lime-making, is extracted on North Goodman street near Northwest avenue, in the quarries of Foery & Kastner, Whitmore, Rauber & Vicinus, and Lauer & Hagaman. The stone is a medium bedded, hard, fine grained, silico-magnesian limestone.

The Guelph rock is quarried most extensively at Rochester, but also at Penfield and East Penfield. Good exposures occur in the quarry of Lauer and May at Brighton, 2 miles east of Rochester (pl. 48). The rock is used for lime and gives a lumpy product of yellowish color. The following analysis sets forth well its magnesian character and its comparative freedom from silica.

Silica	1.12
Alumina	.27
Ferric oxid	.39
Lime	29.38

Magnesia	22.1
Carbon dioxid	47.39
	100.65

If this rock showed this same character at other points, it would show it to be an important bed, and to determine this additional analyses were made by Mr Newland. The first of these represents the average of several samples taken from Snow's quarry at Gates near Rochester.

Silica	.7
Magnesia	20.05
Lime	30.5
Alumina	.95
Ferric oxid	.8
Carbon dioxid	45.24
Ignition	.073
Undetermined	2.687

The last analysis is of a sample from the Copeland quarry in Rochester, collected by G. van Ingen.

Silica	.29
Alumina	.43
Ferric oxid	.46
Loss on ignition	.07
Lime carbonate	56.01
Magnesium carbonate	43.3
	100.56

This shows the rock to be an almost pure dolomite.

The Clinton also occurs in Monroe county, and is to be seen outcropping at the middle falls in the gorge of the Genesee river

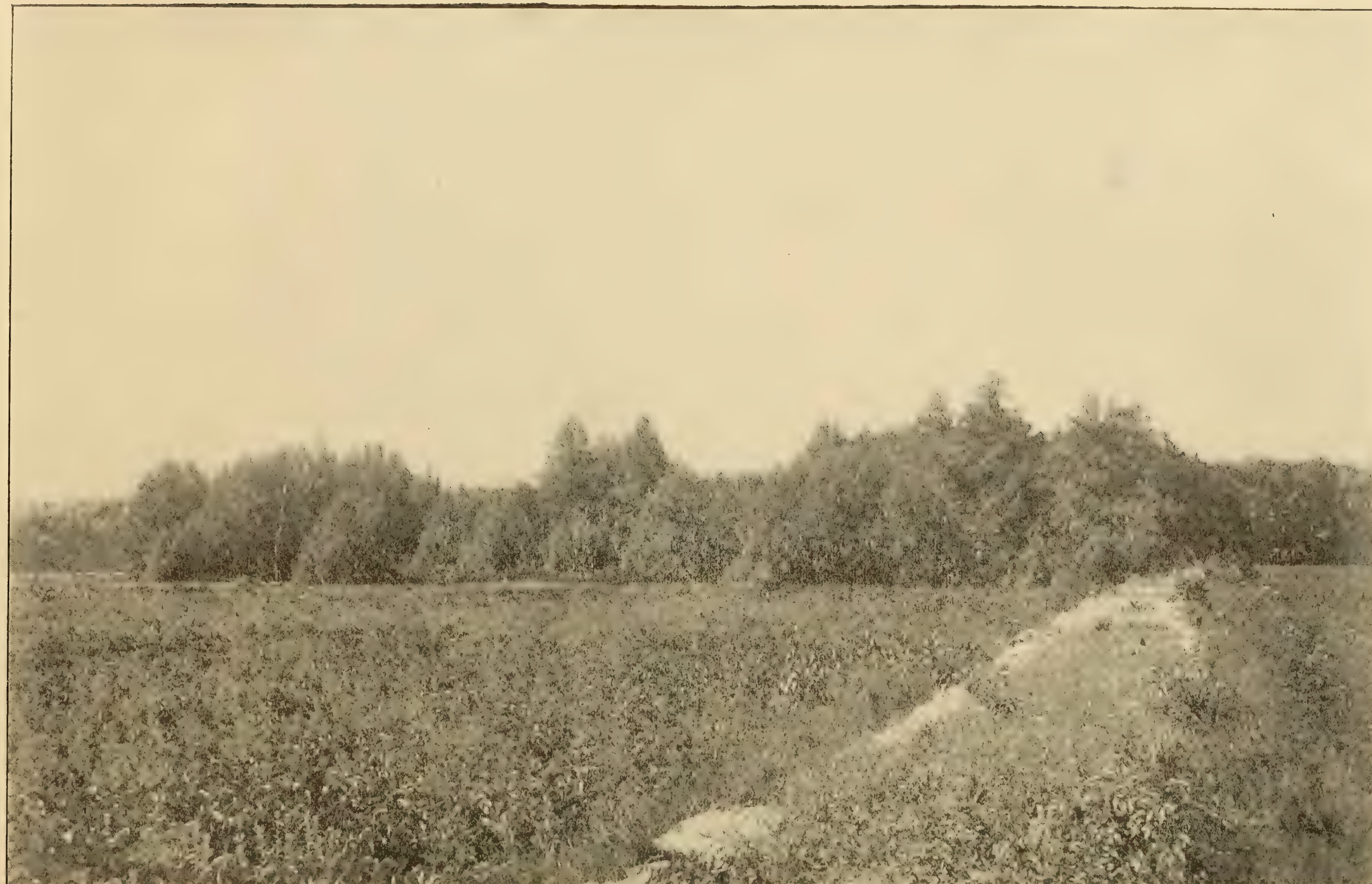
To face p. 796

H. Ries, photo.

Lauer & May's quarry and limekilns, Brighton near Rochester

Plate 49

To face p. 797



H. Ries, photo.

Outcrop of tufa overgrown by cedars on farm of Oliver Allen, near Mumford

at Rochester. No analyses of it are available, but it is thin and unimportant.

The Lower Helderberg limestone occurs sparingly along the southern edge of the county, but is not quarried.

The Quaternary marls and tufas are of some importance in the county. The tufa is at times sufficiently extensive to be used for burning into lime, and it is also massive enough for structural work, a church having been constructed of it at Mumford.

Marl occurs at several localities in the county. Perhaps the largest area is that along Allens creek near Wheatland, this bed extending into Livingston county. At some points the marl is overlain by calcareous tufa to a depth of 3–4 feet. Hall[1] gives the length of the marl swamp as 3 miles, and its breadth as from half a mile to 1 mile. At Mumford the tufa is well exposed in a cedar swamp on the farm of Oliver Allen, ¼ mile east of Mumford station. It contains stems and leaves of cedar (pl. 49). Its composition is as follows:

Silica	.5
Alumina, Ferric oxid	2
Lime carbonate	94.1
Magnesium carbonate	2.3
Insoluble	.5
	99.4

Under the tufa is a bed of marl. On the property of Mr Ward, a florist in Mumford, tufa was encountered in sinking a well, but at this point it was underlain by blue clay. Marl also underlies the cemetery at Mumford.

According to Prof. Hall, another extensive deposit of marl occurs along Mill creek, beginning at its source, and extending

[1] Geol. 4th dist. N. Y. p. 429.

to Cady sound. Tufa forms in exposed situations along the deposit.

Again in the town of Riga on the land of Mr Knowley, a deposit of marl of unknown depth covers 30 or 40 acres. It has been penetrated 10 or 15 feet without finding bottom. The upper 2 feet is very pure, but the lower part is sandy.

The marl has been used for enriching soils, with very good results at several points in the county.

Montgomery county[1]

Good exposures of the Calciferous occur near the New York Central railroad at Amsterdam and St Johnsville, Canajoharie and Tribeshill.

According to Darton the Trenton limestone reaches its maximum thickness at Fort Plain, where it is 9 feet, but decreases to 7 feet at St Johnsville. The limestone varies sometimes, being massive at Tribeshill, and at other places shaly. In the Tribeshill quarries 12 to 15 feet of massive stone is exposed. Other exposures are seen in the quarries north of Amsterdam.

At D. C. Hewitt's quarry, 1 mile north of Amsterdam, the Trenton rock has been used for lime. In the upper quarry the stone is coarse grained, and the layers in upper portion of the quarry are quite impure and shaly. The rock from this upper quarry burns to a brown lime. In the lower quarry, which is just below Hewitt's limekiln, the stone is much purer and more massive than that of the upper quarry. The lower layers are harder, are light gray and are said to make a whiter lime. Under this comes a bed of lime rock which is practically non-slaking and seems to have hydraulic properties. The lime made at this

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[1] Darton, N. H. Preliminary description of the faulted region of Herkimer, Fulton, Montgomery and Saratoga counties (*see* 14th an. rep't N. Y. state geol. p. 33)

—— Geology of Mohawk valley in Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 47th an. rep't N. Y. state mus. p. 603)

Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

quarry is fairly white. The composition of the lower limestone runs:

Silica	6.13
Alumina	.79
Ferric oxid	.61
Lime carbonate	88.49
Magnesium carbonate	2.45
	98.47

The upper beds showed 8.92% of insoluble matter. There is evidently considerable variation in the upper layer, as a comparison of the foregoing analysis with the first of the following three shows. They were made by J. M. Sherrerd and published in 19th annual report U. S. geological survey, pt 6.

	Upper layer	Intermed.	Lower
Silica	1.25	3.82	5.68
Ferric oxid, Alumina	3	1.08	2.76
Lime	52.78	52.46	52.12
Magnesia	.....	.....	.....
Undetermined (CO_2?)	42.97	42.64	39.44

Another limestone quarry has been opened by George Ross on the eastern edge of the town. The rock has thus far been used as building stone. It contains some sandy streaks, which could be separated if the stone were to be burned into lime. The average composition of the stone is:

Silica	7.46
Alumina	2.48
Ferric oxid	1.07
Lime carbonate	71.76
Magnesium carbonate	18.19

This rock is probably Calciferous and not Trenton, judging from its magnesian character. Portions of the rock in the eastern end of the quarry run as low as 4% in insoluble matter.

Other quarries have been opened at Canajoharie, Palatine Bridge, and St Johnsville there being a large number at the last town.

New York county[1]

There is an extensive exposure of white crystalline limestone of Cambro-Silurian age on the west side of the Harlem river, at and south of Kingsbridge; several exposures also occur in Morrisania, and at other points in the county.

The two following analyses of the white limestone from Kingsbridge were kindly furnished by Mr G. A. Stone:

Silica	7.15	10.2
Ferric oxid and alumina	1.06	3.33
Lime	39.57	27.32
Magnesia	10.02	17.99

Niagara county[2]

Limestone passes through the towns of Royalton, Lockport, Cambria and Lewiston. In this county the Guelph, or magnesian member, is missing, but the lower member is of increased thickness. The lower beds overlying the shale are apt to be somewhat silicious, but the upper ones are a crinoidal limestone of greater purity.

The following section of beds composing the Niagara limestone at Lockport is given by Prof. Hall.[3]

5 Thinly laminated, blackish gray limestone with thin laminae of bituminous shaly matter, the whole exhibiting a tendency to a concretionary or contorted structure and the surface of the layers marked by small knobs.

4 Grayish brown bituminous limestone, the lower part with irregular cavities containing spar.

3 A dark colored limestone with cavities and veins of spar often concretionary.

2 Irregularly thick bedded limestone of a light gray color, also containing cavities lined with spar.

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1 Kemp, J. F. Geology of Manhattan island. (*see* Trans. N. Y. acad. sci. 1888. 7: 49–64)

——— Merrill, F. J. H. Crystalline rocks of southeastern New York. (*see* 50th an. rep't N. Y. state mus. 1898. 1: 2–31)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

2 Hall, James. (*see* Geol. 4th dist. N. Y. p. 440)

——— Grabau, A. W. Guide to the geology and paleontology of Niagara Falls and vicinity. (*see* Bul. 45. N. Y. state mus. 1901)

3 Geol. 4th dist. N. Y. p. 89.

1 Encrinal limestone containing numerous crinoid stems. Light gray in color but often spotted with red.

Samples for analyses were taken by the writer from a quarry by a limekiln, 1½ miles east of Lockport and along the canal. The rock in this excavation is a light gray, fine grained, massive limestone containing numerous fossils, which often occur in large aggregates. The upper layers of the quarry are thinner and more argillaceous than the lower ones.

The composition of the Niagara limestone in this quarry is shown by the following analysis made by D. H. Newland.

Silica	7.09
Alumina	2.57
Ferric oxid	.96
Lime carbonate	56.19
Magnesium carbonate	33.42
	100.23

South of the town of Niagara Falls the Niagara limestone is quarried for burning into lime. The quarry is owned and operated by William Messing. The following is an analysis of his stone made by the writer.

Lime	32.21
Magnesia	17.45
Alumina	1.3
Ferric oxid	.75
Silica	1.7
Carbon dioxid	46.79
	100.2

Oneida county[1]

The Helderberg limestones extend across the southern part of the county and are crossed by both the Utica, Binghamton

1 Prosser, C. S. & Cumings, E. R. Sections and thickness of the Lower Silurian formations on West Canada creek and in the Mohawk valley. (*see* 15th an. rep't N. Y. state geol. p. 23)

White, T. G. Report on relations of the Ordovician and Eo-Silurian rocks in portions of Herkimer, Oneida, and Lewis counties. (*see* 51st an. rep't N. Y. state mus. 1: r21)

Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

branch and Utica branch of the Delaware, Lackawanna & Western railroad.

In the eastern part of the county the Trenton limestone extends from Poland to Boonville in a belt several miles wide following the line of the Rome, Watertown & Ogdensburg railroad. The Trenton has been quarried at Prospect along West Canada creek. Prof. Smock states[1] that a sample tested contained 94.82% lime carbonate.

An analysis from this same quarry made by J. D. Irving gave:

Silica	2.59
Alumina	1.21
Ferric oxid	.61
Lime	52
Magnesia	1.04
Carbon dioxid	42
	99.45

Prof. A. H. Chester, of Rutgers college, New Brunswick (N. J.) has kindly furnished the writer with the following analyses.

LOCALITIES	CaO	MgO	Fe_2O_3 and Al_2O_3	CO_2	SiO_2	S	TOTAL
			(2)				
1 Quarries near Clinton, Oneida co. N. Y.	48.68	1.84	1.64	40.29	7.23	.21	99.89
2 Quarry near Clinton (dark)	52.53	.69	.36	42.03	1.92	.....	97.53
3 Same " (light)	35.25	8.94	....	37.52	....	.....	....
4 " " (dark)	43.22	6 08	....	40.65	....	.....	....
5 Another "	48 82	1.48	....	39.99	....	.....	....
6 " "	50 25	1	1.5	40.49	5.53	.3	99.07
7 Oriskany Falls, Oneida co. N. Y.	50.47	.83	1.55	40.57	5.56	.21	99.19
8 Oriskany Falls Oneida co. N. Y.	52.69	.84	1.55	42.33	2.57	.14	100.12
9 Oriskany Falls, Oneida co. N. Y.	50.25	1.11	2.14	40.7	5.66	.18	100.04
10 Oriskany Falls, Oneida co. N. Y.	50.8	1.01	1.35	41.02	5.46	.12	99.76
11 Oriskany Falls, Oneida co. N. Y.	50.93	.85	1.38	40.87	5.82	.07	99.[illegible]2
12 Quarry near Clinton	53.52	.46	.95	42.54	2.48	.04	99.99

The Niagara limestone extends eastward from Madison county as a thin belt passing through Oneida Castle and Vernon.

The Lower Helderberg is prominent in the southern part of the county, with quarries at Oriskany Falls and Caseville.

[1] Bul. 10. N. Y. state mus. p. 246.

Plate 50

To face p. 803

H. Ries, photo.

Upper quarry, Putnam estate, Oriskany Falls

At the former locality there are two quarries just north of the town and close to the Clinton and Binghamton railroad. Both are owned by the Putnam estate, and the upper quarry (pl. 50), or that nearest the town, is used for lime, while the lower one is worked partly for road metal and partly for flux used at the Franklin furnace near Clinton.

The following analysis represents the average of samples taken from the lime quarry.

Silica	4.45
Alumina Ferric oxid	} .3
Lime carbonate	89.4
Magnesium carbonate	5.76
Insoluble	4.75

Onondaga county[1]

Some of the largest limestone quarries in New York state are situated in Onondaga county. The limestones quarried are the Niagara, Lower Helderberg and Upper Helderberg. The purest limestone in the county is furnished by the Stromatopora beds and known as the "diamond blue" rock. Much stone of good grade is however also furnished by the Lower Helderberg rock, notably west of Syracuse.

The Niagara limestone is exposed at several places from the northwest corner of the county to Bridgeport. It generally forms a low ridge. At Diedrich's quarry in Lysander village, where it has been operated for a number of years, the magnesian Niagara limestone is 5 feet thick and of dark gray color. Near Baldwinsville it is 4 feet thick but rather shaly. In Cicero it is 3 feet thick and was formerly used for making lime. As a rule the Niagara limestone can be easily quarried.

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1 Luther, D. D. Economic geology of Onondaga co. (*see* 15th an. rep't N. Y. state geol. p. 237)
Lewis, F. H. The Empire portland cement plant at Warner, N. Y. (*see* Eng. rec. 38, no. 7, p. 136)
Schneider, P. F. Limestones of central New York. (*see* Stone, 18: 26)
Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

The Lower Helderberg rocks of Onondaga county are mostly dark blue and fine grained, occurring in beds 1 to 5 feet thick. They weather to a bluish gray. Most of them are fairly pure but at times contain some magnesia or clayey material. The pure beds are the important lime producers and are used for structural work in the county.

Two beds of hydraulic limestone lie near the top of the group, and according to Luther are often separated by 4 feet of impure limestone. In the eastern part of the county the upper layer is 4 feet thick, but it pinches out in the Splitrock quarry west of Syracuse to reappear again near Marcellus Falls, where it is 2 feet 10 inches thick in Watkins quarry, and reaches 4 feet in Corrigan's quarry at Skaneateles. As at the latter place it is only separated from the lower bed by a shaly layer, the two practically form one bed 9 feet 6 inches thick.

At Manlius the beds are separated by 4 feet of blue limestone and at Street's quarry near Onondaga Hill by 1 foot 8 inches, at Marcellus Falls by 1 foot 7 inches, and at Skaneateles they are together.

Luther gives the following thicknesses for the lower waterlime layer in Onondaga county.

	FEET	INCHES
Manlius, J. Behan's quarry	4	
Jamesville, E. B. Alvord	4	
Brighton, Britton and Clark	5	
Skaneateles, Corrigan's quarry	5	

At Splitrock the upper member occurs in the southeastern part of the quarry but is wanting in the western portion, its place being occupied by a 9 foot bed of blue limestone.

The hydraulic limestone in Onondaga county is brittle, compact, fine and even grained. It is dark colored with a conchoidal fracture but weathers to a light color. The beds are generally well defined but do not as a rule contain any fossils. The rock was discovered in 1818 in connection with work on the Erie canal. As in other cases attempts were made to burn the stone

To face p. 804

Cement rock.

Cement rock.

H. Ries, photo.

Behans quarry, Manlius

Plate 52

To face p. 804

H. Ries, photo.

Brown's cement kiln and mill on left near Manlius

Plate 53

To face p. 805

H. Ries, photo.

Upper quarry, Alvord & Co., Manlius. Stone used by Solvay process co.

Plate 54

To face p. 805

H. Ries, photo.

A. E. Alvord & Co.'s quarry south of Jamesville, yielding limerock and waterlime

Plate 55

To face p. 805

H. Ries, photo.

"Swamp" quarry of Alvord & Co., Jamesville

for lime, but it was found that it would not slake. The cement rock quarries are generally near the summit of the Helderberg escarpment, and covered by a little other rock, which is first stripped and used for building purposes or road material.

The limestone obtained from the Stromatopora beds is locally known as diamond rock or diamond blue, and is the stratum commonly used for the manufacture of lime; the same kilns are used for burning either lime or cement. Those used in Onondaga county are oval with a diameter of 10 feet at the top, 12 in the middle and 3½ at the bottom. They are 28 to 42 feet deep and are generally built of limestone with a lining of fire brick. In starting the kiln a cord of 4 foot wood is put in the bottom, over this 4 inches of anthracite coal, then 1 foot of limestone, more coal and alternating layers of stone and coal to the top. It takes 10 tons of coal and 15 cords of stone to fill a kiln, and this gives 1500 bushels of lime. After the kiln has been burning two or three days the first draw of 250 to 300 bushels can be made at the bottom of the kiln. The cement is of course ground before use. The most important producers in the county are: A. E. Alvord of Syracuse, quarry and kilns at Syracuse; J. Behan estate, quarry and kilns at Manlius; E. B. Alvord & Co. Jamesville; Britton & Clark, Rock Cut.

Most of the limestone quarried in the county is used by the Solvay process co., of Syracuse, in the manufacture of soda ash. This firm has a very large quarry at Splitrock, about 5 miles west of Syracuse, from which it has been taking over 250,000 pounds annually. Recently the supply has been decreasing, and the company is obtaining stone in part from A. E. Alvord & Co.'s quarry at Manlius.

No. 1 shows the composition of lime made from the stone in E. B. Alvord & Co.'s quarry at Jamesville, the analysis being made by F. E. Engelhardt.

Lime	91.93
Magnesia	3.06

Insoluble	1.88
Sulfuric anhydrid	.73
Ferric oxid and alumina	2.03

The composition of the limestone in Alvord's quarry is:

Silica	1.6
Alumina and ferric oxid	.7
Lime carbonate	97
Magnesium carbonate	1.11

This same quarry also contains several layers of cement rock, of which the following are analyses.

	Upper layer	Lower layer
Silica	10.97	10.95
Alumina	4.46	5.32
Ferric oxid	1.54	1.3
Lime	27.51	30.92
Magnesia	16.9	13.64
Carbon dioxid	37.94	38.31

The composition of the blue lime in the Splitrock quarry of the Solvay co. is as follows:

Silica	5.35
Alumina	.56
Ferric oxid	.61
Lime carbonate	85.41
Magnesium carbonate	18.86

The Upper Helderberg, in Onondaga is a light gray semicrystalline limestone, the layers being separated by partings of shale. The rock is at times variable in its character and may at times

Plate 56

To face p. 807

H. Ries, photo.

Marl pit at Warners

become argillaceous. Cherty layers are sometimes common in the upper part of the formation.

The chief value of the Corniferous is as a building stone, though many portions of it are adapted to the manufacture of lime. Many quarries have been opened in it, and the largest now in operation is at the Indian reservation in the Onondaga valley.

The Onondaga group of limestones has a total thickness of 60 feet at the eastern edge and 70 feet at the western edge. The Corniferous is usually found at the top of the Helderberg escarpment. At Green lakes, 2 miles north of Jamesville, 25 feet of Onondaga stone is exposed. At the Splitrock quarries about 12 feet of Corniferous is exposed in the southwest corner, and in A. E. Alvord's quarry, ½ mile east of Manlius, 17 feet 6 inches is exposed. Maylie's quarry, ½ mile southeast of Marcellus, shows the upper layers of the Corniferous, and they are also to be seen in John Clancy's and M. Hogan's quarry near there. Maylie's stone is used in part for lime.

Marl abounds[1] in many of the small lakes around Dewitt and Manlius. Cicero swamp is underlain by an extensive deposit, and the marshes near Dewitt and Manlius also contain it. Other beds are in Camillus, Elbridge and southern part of Van Buren near the Erie canal.

Two important Portland cement plants, the one at Jordan, the other at Warner utilize this material.

They are described in another portion of the report.

Ontario county[2]

The Lower and Upper Helderberg cross the county, the northern boundary of the belt coinciding approximately with the

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[1] Luther, D. D. Economic geology of Onondaga county. (*see* 15th an. rep't N. Y. state geol. p. 237)

[2] Clarke, J. M. Brief outline of the geological succession in Ontario county, N. Y. (*see* 4th an. rep't N. Y. state geol.)
Hall, James. Geol. 4th dist. N. Y. p. 453.

Lehigh Valley railroad. Quarries have been opened in it at Phelps.

Hall[1] states that marl underlies the marsh bordering Flint creek south of the village of Bethel, and probably occurs under the swamp near Victor, as well as in the swamps at the heads of Hemlock and Canadice lakes.

Orange and Rockland counties[2]

In Rockland and Orange counties there begins another series of belts of the Cambro-Silurian limestone formation, which extend in a northeasterly direction. These same belts continue across the river into Dutchess county and also extend up into Columbia county. In the latter, however, they are so unimportant as not to be worth considering.

The Cambro-Silurian limestones are found at several places in Orange county. One area occurs around Central Valley (pl. 57) and Turner, extending thence westward to Monroe. It is finely crystalline, light bluish gray, and rather silicious; still it is used for lime. Another area extends from a point about 2 miles south of Sugarloaf past Stone Bridge, Warwick and New Milford into New Jersey.

Its character in this area is similar to that of the limestone around Monroe and Turner, and a quarry has been opened in it 2 miles south of Goshen, on the road to Warwick.

It may at times become quite silicious, showing as much as 18% silica, and there may also be a variation between the different

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1 Geol. 4th dist. N. Y. p. 458.

2 Barrett, S. T. Notes on the Lower Helderberg rocks of Port Jervis, N. Y. (*see* Am. jour. sci. 3d ser. 13: 385)

Darton, N. H. Area of Upper Silurian rocks near Cornwall Station, eastern central Orange county, N. Y. (*see* Am. jour. sci. 1886. 3d ser. 31: 209)

—— Geologic relations from Green pond, N. J., to Skunnemunk mountain, N. Y. (*see* Bul. 5. Geol. soc. Am. p. 367)

Dwight, W. B. Calciferous as well as Trenton fossils in the Wappinger limestone at Rochdale and a Trenton locality at Newburgh, N. Y. (*see* Am. jour. sci. 1880. 19: 50)

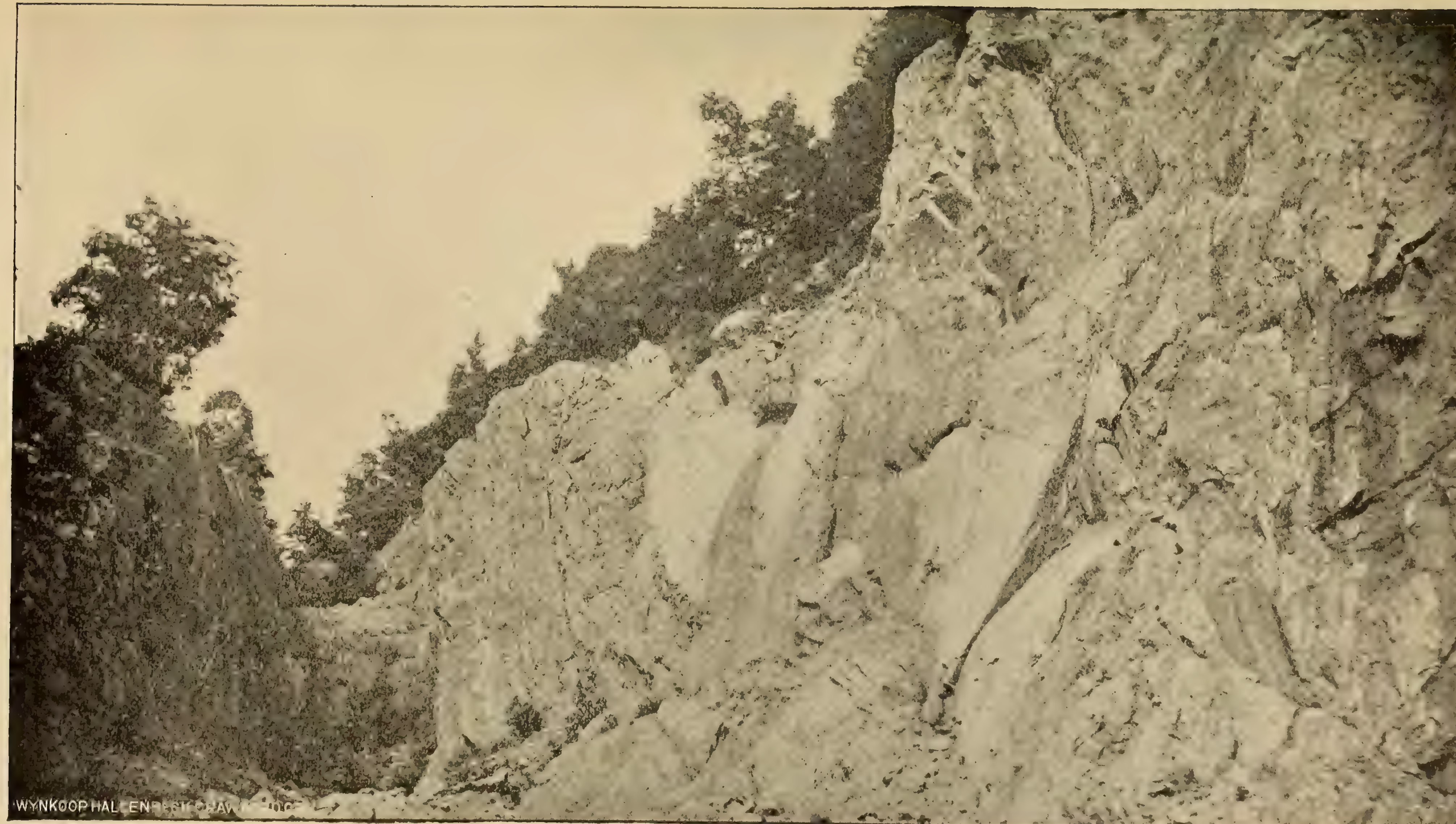
Kemp, J. F. & Hollick, A. The granites at Mounts Adam and Eve. (*see* Annals N. Y. acad. sci. 7: 638)

Ries, Heinrich. Report on the geology of Orange county. (*see* 15th an. rep't N. Y. state geol. p. 393)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

Plate 57

To face p. 808



Limestone quarry at Arden

H. Ries, photo. Limestone quarry, Tomkins Cove, Rockland co. Metamorphosed Calciferous limestone

layers in the same quarry, one perhaps containing only 2%, while the others may have 15% or 18%.

An area of white limestone extends from Florida through Pine Island and Amity into New Jersey. This is a highly crystalline, metamorphosed limestone, which also occurs in a broad belt that extends southwest from Florida through Big Island and Gardinerville into New Jersey. It possesses the same character as the other belt. A small area of Trenton limestone is found along the railroad between Neelytown and Campbell Hall. This has been used to a small extent for lime. The Cambro-Silurian limestones also outcrop both southwest, west and north of the city of Newburgh.

The character of these Cambro-Silurian rocks of the Orange and Rockland county belt may be judged from the following analyses made of samples collected from different parts of the quarry, the analyses in each case representing the average of the quarry.

The first one of the magnesian limestone from Tompkins Cove, (pl. 58) is as follows:

Lime	26.34
Magnesia	16.74
Carbonic acid	39.1
Alumina	4.13
Ferric oxid	1.05
Silica	12
	99.36

This analysis shows that the stone is both magnesian and highly silicious. The following analysis of the Cambro-Silurian limestone from Miller Bros.' quarry on the southwestern edge of Newburgh indicates the rather constant character of the stone. It runs:

Lime	27.75
Magnesia	17.65

Carbonic acid	40.99
Alumina	1.93
Ferric oxid	1.8
Silica	10.46
	100.58

This stone is used to a small degree for lime-making.

While swampy tracts are abundant in Orange county, the writer has not been able to prove the existence of marl under any of them.

The Lower Helderberg limestones, though known to occur along Schunemunk mountain in the eastern part of Orange county, are not important there, but do form a prominent strip along the western side of Shawangunk mountain. The Pentamerus is exposed in a quarry about 4 miles southwest of Otisville and was at one time burned for lime (pl. 59). A much better section is exposed in Bennett's quarry east of Port Jervis, and adjoining the road to Middletown at a point about 1 mile east of TriStates. This stone would be available for Portland cement manufacture.

The Corniferous or Upper Helderberg forms a low ridge east of Port Jervis, and also underlies TriStates point. It is full of chert nodules.

Orleans county[1]

This county, like several of the others bordering on Lake Ontario, contains a broad band of the Niagara limestones. The material utilized in every case for the manufacture of lime is the upper member. Quarries are in operation at Barre Center, south of Albion, (pl. 60) Clarendon and Shelby.

At the first named locality, the material used is chiefly disintegrated surface blocks. At this point one of the quarrymen, B. Johnson, recognizes three types of stone, viz, the porous, or

[1] Hall, James. Geol. 4th dist. N. Y. p. 433.

Quarry in Pentamerus limestone, southwest of Otisville

H. Ries, photo.

Field south of Albion, where Guelph boulders are quarried for lime

Plate 61

To face p. 811

H. Ries, photo.

Johnson lime kiln, Barre Center

second grade rock, the massive, or first grade, and a third type of more earthy appearance, which slakes very readily when burned. The product from Johnson's (pl. 61) and also T. F. Staine's kiln is sent largely to Batavia.

Extensive deposits of marl occur near Clarendon, southwest of Holly, but the material is not worked. Marl is said to be found 2½ miles north of Medina,[1] and southwest of Clarendon. Some effort has been made to employ it for Portland cement.

Putnam county[2]

Quarries exist at Patterson and at Towners in Putnam county. The quarry at Towners is 1 mile northwest of the New England railroad. The stone is gray and white, coarsely crystalline and contains many crystals of white or light green pyroxene scattered through it. Mica flakes are also abundant in the rock. It is a magnesian limestone with considerable silica in its composition. The quarry at Patterson is on the Haight property half a mile southeast of the railway depot. The opening is about 15 by 40 feet in area and 60 feet deep. A number of blocks of stone have been taken out, but all show the rock to be full of mineral impurities, such that it would not make a very high grade lime.

Rensselaer county[2]

A belt of impure limestone of Cambro-Silurian age extends from Lebanon Springs to Petersburg, but outcrops are scarce.

Another small area extends from the vicinity of North Petersburg to Eagle Bridge and underlying an area several miles wide west of Hoosick Falls. At the last locality a number of small quarries have been opened on a hill west of the town, and show well the varying character of the stone, as well as its purity in certain beds. The rock varies from a nearly pure limestone to a black calcareous slate. It has been used to some extent for flux

1 Hall, James. Geol. 4th dist. N. Y. p. 437.
2 Mather, W. W. Geol. 1st dist. N. Y. 1843.

in a local furnace, while some has been shipped to Troy, and at times it has also been used for lime manufacture.

The best stone is found in Cornelius McCaffery's quarry. The section there is nearly 60 feet thick, rather flinty in the upper part but in the lower yielding stone which analyzed:

Silica	1.2
Ferric oxid	1.5
Alumina	2
Lime	34.11
Magnesia	8.97

St Lawrence county[1]

The Trenton-Chazy limestones extend along the St Lawrence river from Chippewa Bay to the northeastern edge of the county. Their southeastern boundary passes through Flackville, Norwood, North Stockholm, Brasher Falls and Fort Covington Center.

At Ogdensburg the stone has been quarried for lime manufacture about a mile west of the town. The stone is thin bedded, and only the upper layers of the quarry are used for lime.

The following analyses show not only the dolomitic character of the rock but also the greater freedom from silica of the upper layers.

Upper stone, Howard's quarry, Ogdensburg:

Silica	4.42
Alumina	2.23
Ferric oxid	.16
Lime carbonate	55.87
Magnesium carbonate	37.74
	100.42

[1] Smyth, C. H. jr. A geological reconnaissance in the vicinity of Gouverneur, N. Y. (*see* Trans. N. Y. acad. sci. 12: 97)

—— Preliminary examination of the general and economic geology of four townships in St Lawrence and Jefferson counties, N. Y. (*see* 47th an. rep't N. Y. state mus. p. 687)

Lower stone, Howard's quarry, Ogdensburg:

Silica	17.28
Alumina	5.21
Ferric oxid	.92
Lime carbonate	58.17
Magnesium carbonate	18.46
	100.04

The crystalline limestones form a belt many square miles in extent, stretching in a northeast and southwest direction; in addition there are small scattered patches, which are irregularly distributed throughout the county. According to Smyth the largest limestone belt is that which is traversed longitudinally by the Rome, Watertown and Ogdensburg railroad, and extends from Antwerp to a point 2 miles east of De Kalb Junction. While it is thus seen that the limestone underlies a considerable area, at the same time, owing to a scarcity of outcrops, its presence is not always noticeable. The linear extent of this belt from Antwerp to its probable end in Canton is 35 miles. Its width in a northwest and southeast direction is variable. It is 2 miles at Antwerp, 6 to 8 at Gouverneur, but then narrows again. The limestone is highly crystalline in character, and varies in color from a white to a dark bluish gray. It is unfortunately often rendered impure more or less by scattered grains or somewhat similar masses of minerals, of which the most important are serpentine and tremolite. In some localities these crystalline limestones reach a high degree of purity. The following two analyses were kindly furnished me by Prof. Priestley, of St Lawrence university. No. 1 is a stone used for lime from a locality on the road to Colton and 6 miles from Canton. No. 2 is from Steven's quarry on Grass river 1 mile above Canton. The second one is not used for lime.

	1	2
Silica	.5	1.12
Iron oxid and alumina	1.3	1.89
Lime carbonate	88.67	76.48
Magnesium carbonate	9.53	19.97
	100	101.11

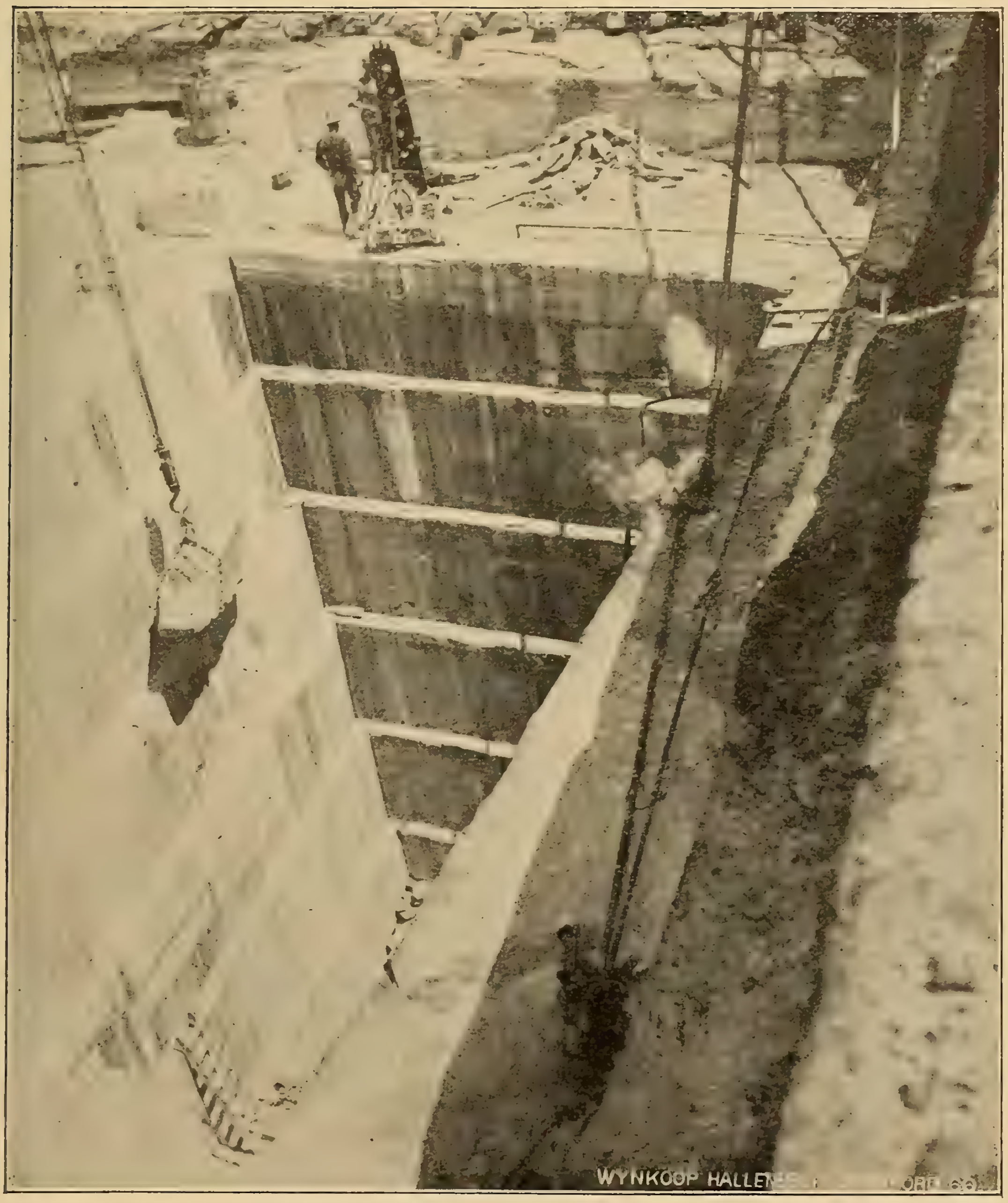
At Gouverneur extensive quarries have been opened for obtaining marble, and much of the refuse is used for lime. This stone often runs low in impurities, as indicated by the following analyses made by J. D. Irving:

Silica	1.85
Alumina	.23
Ferric oxid	.38
Lime carbonate	92.29
Magnesium carbonate	4.28
	99.03

The crystalline limestone is well exposed at Harrisville (N. Y.) in the quarries of the Harrisville marble co., which lie about half a mile from the Carthage and Adirondack railroad. The rock there approaches very closely in composition to that at Gouverneur. There is a considerable ledge of crystalline limestone on the Hungerford farm, near Lewisburg, about 4½ miles north of the natural bridge. It is rather far from a railroad, but it has been estimated that it could be put on the car at Natural Bridge for $1.35 a ton. The stone is coarsely granular but not very hard. Certain portions of the rock are very white, evidently quite pure but rather free from silica. Other portions contain an abundance of mica grains.

The following analysis of these white dolomites was made by G. J. Donohue and furnished to the writer by C. Graves of Natural Bridge (N. Y.)

Plate 62 To face p. 814



J. N. Nevius, photo.

Empire marble co.'s quarry near Gouverneur, St Lawrence co. pre-Cambrian

Silica	.24
Ferric oxid alumina	.24
Lime	22.43
Magnesia	29.48
Carbonic acid	47.73
	100.12

In addition to the main belt of crystalline limestone mentioned, there are a number of smaller areas, which are quarried at Bigelow, Brasie Corners, Crary Mills, East Pitcairn, Hickory, and Rossie.

That from Rossie which is quarried by C. Williams & Co. is used by the Dexter sulfite pulp and paper co., which made the following analysis of the lime.

Lime	91.72
Magnesia	7.52
Ferric oxid and alumina	.38
	99.62

Saratoga county[1]

The limestones are mostly Calciferous, though some Trenton occurs. Owing to their irregular distribution and faulted relations, the occurrences can be best determined from the accompanying map. Most of the quarries are located in the Calciferous, but there are also some excellent exposures of Trenton, fully equal to those along the Hudson river at Glens Falls.

The composition of some of the Calciferous beds may be judged from the analysis given below. At Sandyhill, both the Calciferous and Trenton limestone occur. The Calciferous is quar-

[1] Darton, N. H. Geology of the Mohawk valley, in Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 47th an. rep't N. Y. state mus. p. 603)

—— Preliminary description of the faulted region of Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 14th an. rep't N. Y. state geol. p. 33)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

ried by Higley, Monty & Co., but, owing to its silicious nature, it has been used only for building stone. It analyzed

Lime	29.05
Magnesia	12.8
Ferric oxid	1.02
Alumina	.46
Carbonic acid	38.6
Insoluble residue	18.04

The Trenton limestone is exposed about 1½ miles east of the canal, and the section is very similar to that found at Glens Falls, the upper layers being somewhat impure and the lower layers showing 8 feet of black limestone evidently of considerable purity.

Other quarries are at Saratoga Springs and South Glens Falls.

Schenectady county [1]

This county is destitute of limestones except a small area of Calciferous in its extreme northwestern corner, and a bit of Lower Helderberg in the southwestern portion. Both are of small extent. Limestone is quarried at Hoffmans.

Schcharie county [2]

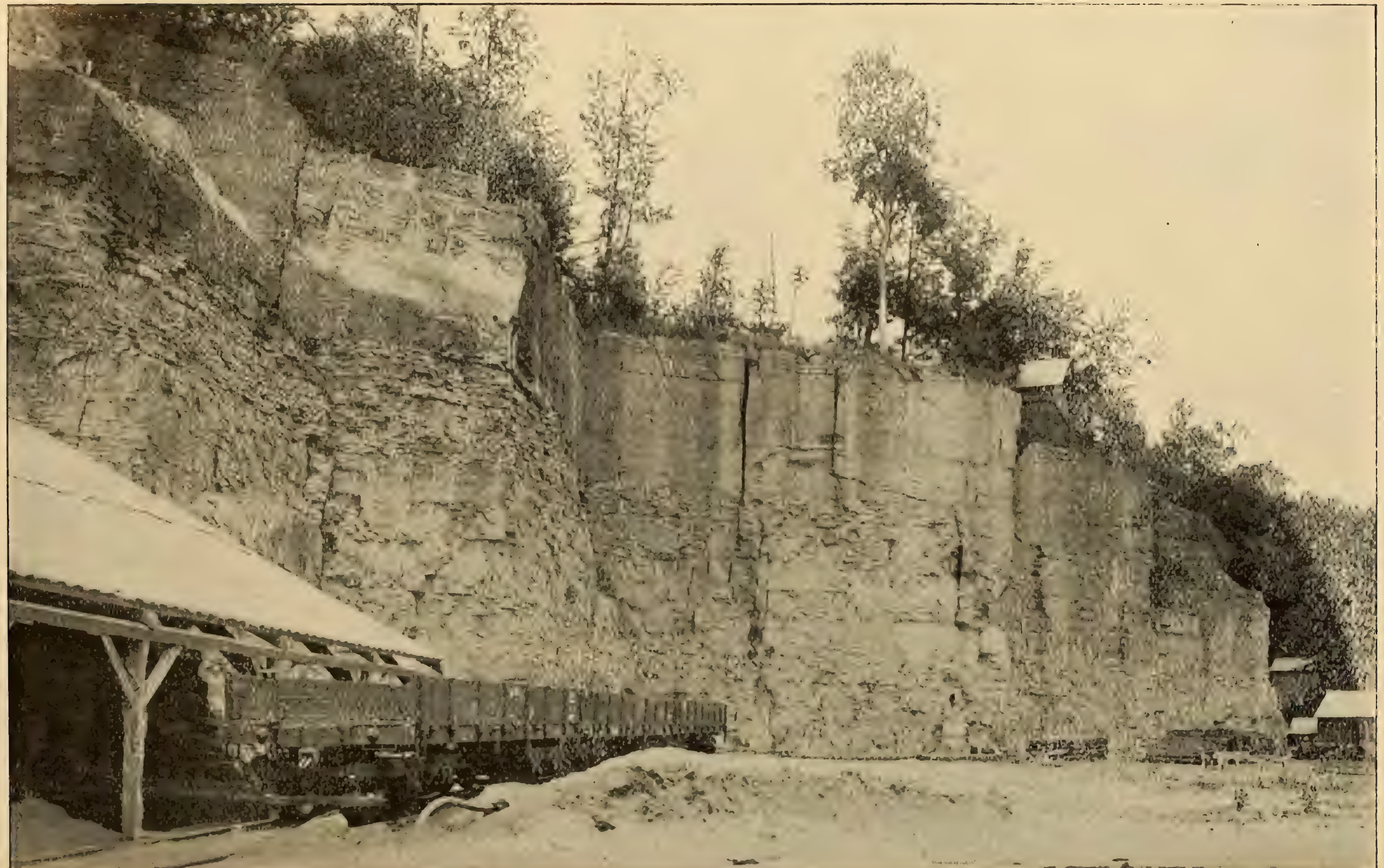
This county exhibits a great thickness of Helderberg limestones, which have been opened up at Schoharie, Howe Cave, Barnerville, Cobleskill, Middleburg, Sharon Center, Sharon Springs and Cherry Valley. The general section can be obtained from the account of the Helderberg limestone formation in another portion of the report.

At both Schoharie and Howe Cave there is a splendid development of the lower Pentamerus and Tentaculite members. The former beds, which are 60 to 70 feet thick, are hard, massively bedded, vertically jointed limestones, of bluish gray color.

The Tentaculite beds, underlying the Pentamerus, are thin bedded, dark blue limestones, whose layers vary from 2 to 3 inches. At Howe Cave and Schoharie their thickness is 40 feet.

[1] Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.
[2] Mather, W. W. Geol. 1st dist. N. Y. 1843.

To face p. 817



H. Ries, photo.

Quarry of Helderberg cement co. at Howe Cave

In the quarries of the Helderberg cement co. (pl. 63) at Howe Cave, 120 feet of the two limestones just mentioned is exposed. They are used for the manufacture of Portland cement, being mixed with clay. Underlying the limestone is a bed of natural rock cement, which is also utilized. The following analyses were furnished by C. R. Ramsey, superintendent of the works.

	Gray stone	Blue limestone	Clay
Lime	52.18	52.58	2.9
Magnesia	1.27	.79	.....
Silica	2.7	3.12	71.67
Alumina and ferric oxid	1.64	.93	15.08
Sulfur	.17	.24	.....
Ignition	15.13	18.8	5

The first two analyses are not very consistent; for it is hard to conceive how a stone containing 52.18% of lime could yield only 15.13% on ignition.

The cement rock is said to yield on analysis:

Lime carbonate	55.17
Magnesium carbonate	19.71
Silica	12.89
Ferric oxid and alumina	11.15
Water	.66

Another analysis of Howe Cave limestone, made by C. A. Schaffer,[1] gave:

Lime carbonate	97.24
Magnesium carbonate	1.39
Ferric oxid and alumina	.73
Silica	1.27
Sulfur	tr.
Phosphoric acid	none
	100.63

[1] 20th rep't U. S. geol. sur. pt 6, p. 428.

At Barnerville, between Howe Cave and Cobleskill, a very large quarry has been opened in the same limestone, for building purposes (pl. 64, 65). The stone is said to yield on analysis:

Lime	51.05
Magnesia	1.65
Silica	4.31
Alumina and ferric oxid	.97
Sulfur	.29
Carbon dioxid	41.9
	100.17

Schuyler county[1]

South of Alpine station on the Lehigh Valley railroad is a large tamarack swamp, whose surface is underlain by from 3–8 feet of muck. Below this is found a deposit of marl which varies in thickness from 2–10 feet, being as much as the latter in many spots.

The property is owned by J. Hinman.

Seneca county[1]

The Upper Helderberg formation covers a belt widening westward, which extends from opposite Union Springs on Cayuga lake westward toward Geneva on the south and Thornton Corners on the north. It is quarried at both Seneca Falls and Waterloo, the quarries being mostly in the Seneca beds, but partly in Corniferous. At Seneca Falls the quarry is operated by G. J. Fisher, and at Waterloo the quarry operators are D. Babcock, Edson Bros., G. C. Thomas & Bros., B. Frank. The following section is from Babcock's quarry (pl. 66). Beginning at the top there is:

Dark, fine grained limestone	0′	14″
Cherty limestone	6′	0″
Cherty limestone	2′	0″
Shale	0′	10″
Two 17 inch layers, fine grained limestone,	2′	10″

[1] Hall, James. Geol. 4th dist. N. Y. p. 449.
Lincoln, D. F. Geology of Seneca county. (*see* 15th an. rep't N. Y. state geol. p. 57)

Plate 64

To face p. 818

H. Ries, photo.

Quarry at Barnerville, near Howe Cave

Plate 65

To face p. 818

H. Ries, photo.

Quarry at Barnerville, near Howe Cave

H. Ries, photo.

View of Babcock's limestone quarry, Waterloo

Plate 67

To face p. 819

H. Ries, photo.

Valley at Perkinsville, underlain with marl

The 14 and 17 inch layers make good lime and are shipped to Geneva for burning. The average composition of the rock is as follows:

Silica	14.85
Alumina	7.18
Ferric oxid	1.57
Lime	40.23
Magnesia	1.95
Carbon dioxid	33.76
	99.54

The Tully limestone lies between the Hamilton and Genesee shales, and is of importance, as it is the most southern lime rock of central New York. It outcrops at several localities according to D. F. Lincoln.[1]

The most northern is about a mile west of Hayt Corners; a second exposure is at Willard hospital, where it forms the cascades near the reservoir; another on Seneca lake 1 mile south of Willard landing, where 15 to 20 feet is exposed; still other outcrops are in the creek near Highland station and at Lodi.

A quarry has been opened in it 1 mile southeast of Hayt Corners.

Steuben county[2]

No beds of limestone are found within the county, but an extensive deposit of marl is dug at Perkinsville and Wayland (pl. 67). It lies in a great swampy area, and furnishes material for two Portland cement works, that of Millen & Co., of Wayland, and the Wayland Portland cement co., located at Perkinsville. Though the deposit is of considerable extent, it is not underlain by clay, which has to be brought from Morrisville.

Tompkins county[3]

The only limestone formation is the Tully, which outcrops on the eastern shore of Cayuga lake between Lakeridge and Lansing along the Auburn branch of the Lehigh Valley railroad.

1 Lincoln, D. F. Geology of Seneca county. (*see* **15th an. rep't N. Y.** state geol. p. 57)
2 Hall, James. Geol. 4th dist. N. Y. p. 480.
3 Hall, James. Geol. 4th dist. N. Y. p. 475.

The ledges are most prominent at the track level about ¾ mile south of Lansing. The stone is fine grained, moderately hard, and shows occasional impure layers, but comparatively few chert nodules, the impurities being mostly iron and clay. It is a massive rock, with layers 2 to 3 feet thick, the total thickness being about 20 feet, and is favorably situated for either rail or water shipment.

An analysis made of samples taken by the writer from the ledge south of Lansing showed:

Silica	5.7
Alumina Ferric oxid	2.1
Lime carbonate	88.5
Magnesium carbonate	1.4
Insoluble	8.8

Ulster county[1]

The limestone formations occurring in Ulster county together with their thickness are as follows:

	Feet	
Onondaga	60	Cherty
Upper shaly limestone	30–125	Impure
Becraft limestone	20–30	Fairly pure
Lower shaly limestone	60	Impure
Pentamerus limestone	30–60	Dark massive
Tentaculite limestone	20–40	Thin bedded
Cement series	20–50	Cement and waterlime
Niagara limestone	0–45	
Wappinger limestone	200	Silicious

[1] Darton. Geology of Ulster county. (*see* 13th an. rep't N. Y. state geol. p. 297).

Dale, T. N. The fault at Rondout. (*see* Am. jour. sci. 1879. 18: 293)

Davis, W. M. The little mountain east of the Catskill. (*see* Appalachia, 3: 20)

———. Non-conformity at Rondout N. Y. (*see* Am. jour. sci. 1883. 26: 389)

———. Becraft mountain. (*see* Am. jour. sci. 1883. 26: 381)

———. The folded Helderberg limestones. (*see* Bul. Mus. comp. zool. Harvard col. 7: 311)

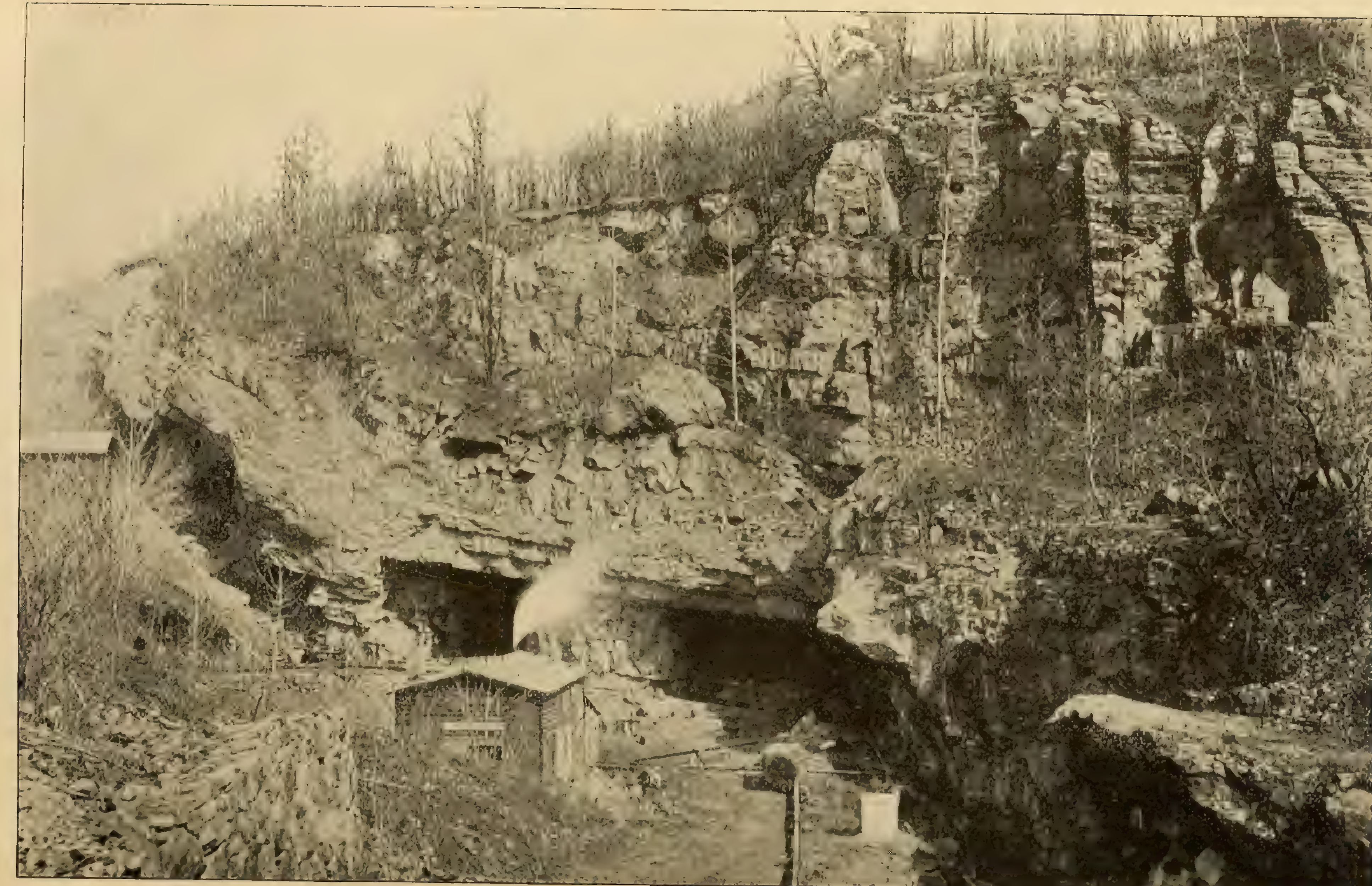
Lindsley. Geology of the cement quarries. (*see* Poughkeepsie soc. nat. sci. 11: 44)

Nason, F. L. Economic geology of Ulster county. (*see* 13th an. rep't N. Y. state geol.)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

Plate 68

To face p. 821

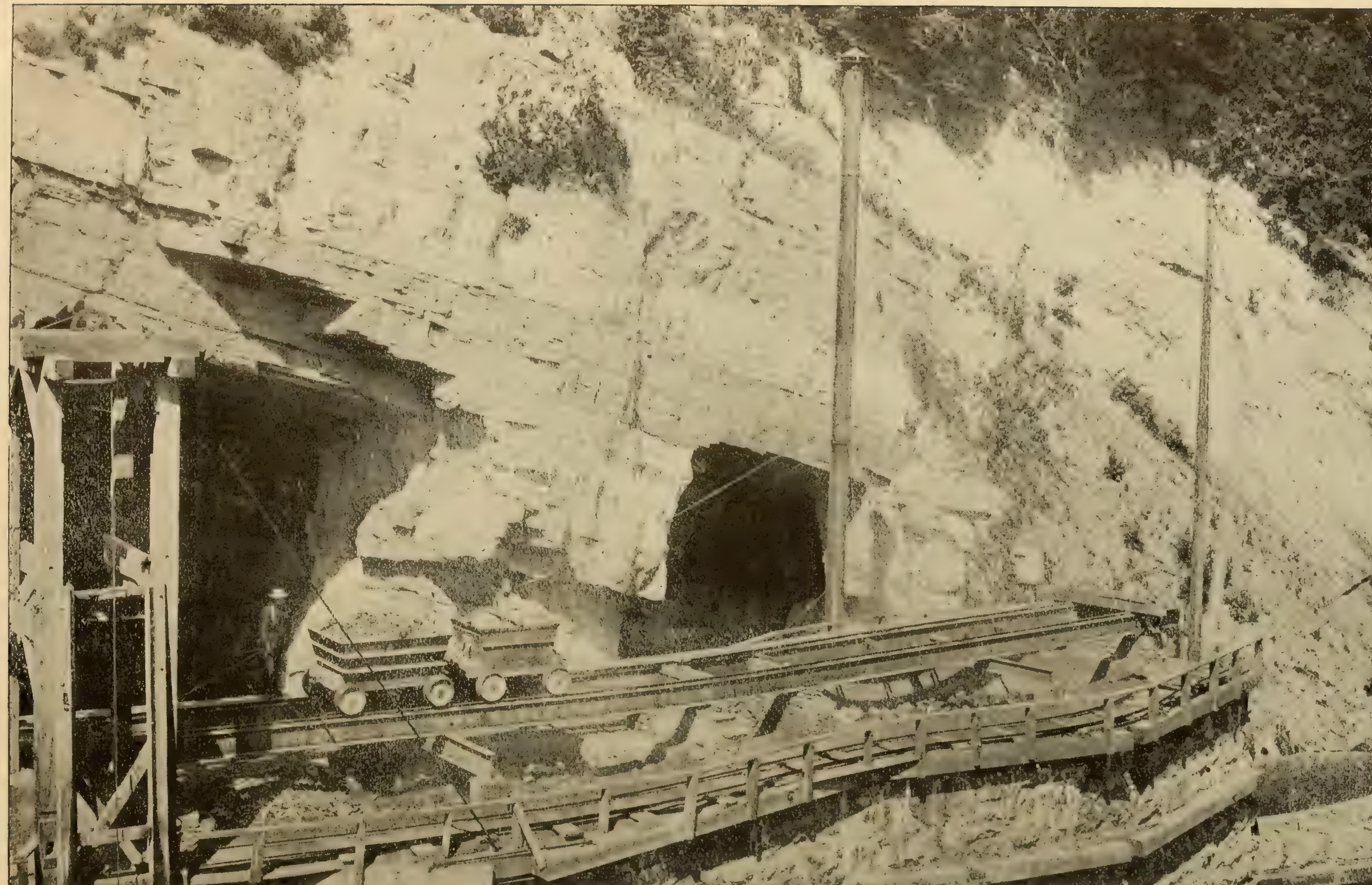


H. Ries, photo.

Quarry N. Y. cement co., Rosendale

Plate 69

To face p. 821



H. Ries, photo.

East end of quarry at Rosendale

Of these the Becraft and the cement beds are the most important.

Onondaga limestone has been quarried at a number of localities for burning into lime. The stone is generally light blue gray, dense and massive. Unfortunately a common feature is the presence of layers of chert, though these may be locally absent. They predominate chiefly in the upper beds.

Darton states[1] that the outcrop of the Onondaga limestone is practically continuous from the northeastern corner of the county to Wawarsing township. Around Kingston its area widens greatly, on account of the presence of folds, and most of the upper part of the city is built on it. Southward by Hurley and Marbletown the Onondaga formation is prominent in the ridge sloping westward to Esopus creek. Exposures also abound along the West Shore railroad northward from Kingston, and, from west of Saugerties to Asbury, along and near the road passing through Cedar Grove and Katsbaan.

Through its whole extent the upper shaly limestone exhibits a large amount of argillaceous and silicious impurities. The beds are massive, but the rocks possess a slaty cleavage, and these properties aid in the formation by them of small rough ridges. It extends across the county parallel with the Onondaga limestone. As far as known, it is not available for any of the uses treated of in this report. The upper shaly overlies the Becraft limestone.

In Ulster county the Becraft is the purest limestone of the whole Lower Helderberg series. The beds are massive, bluish gray to reddish limestone, of a semicrystalline nature and highly fossiliferous. Scattered through the rock are saucer-shaped masses of white, crystallized lime carbonate, from 1 to 2 inches in diameter and representing the bases of crinoid heads. The formation according to Darton varies from 20 to 30 feet in thickness.

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[1] Geology of Ulster county. (*see* 13th an. rep't N. Y. state geol. p. 301)

Extensive quarries have been opened in it near Rondout, Eddyville and Whiteport. The lime made from it is of good quality, lumpy but slightly brown in color. The Becraft limestone extends across the eastern portion of the county from north to south.

It is well exposed between Saugerties and Rondout and about Wilbur and Whiteport, but exposures of it are rare southwest of this latter locality except at Mill Hook and Highfalls.

Samples for analysis were collected from the quarry of the Newark cement co. at Rondout, and the average of these gave:

Silica	3.87
Ferric oxid	1.34
Alumina	1.07
Lime	54.11
Magnesia	tr.
Carbon dioxid	40.6
	100.99

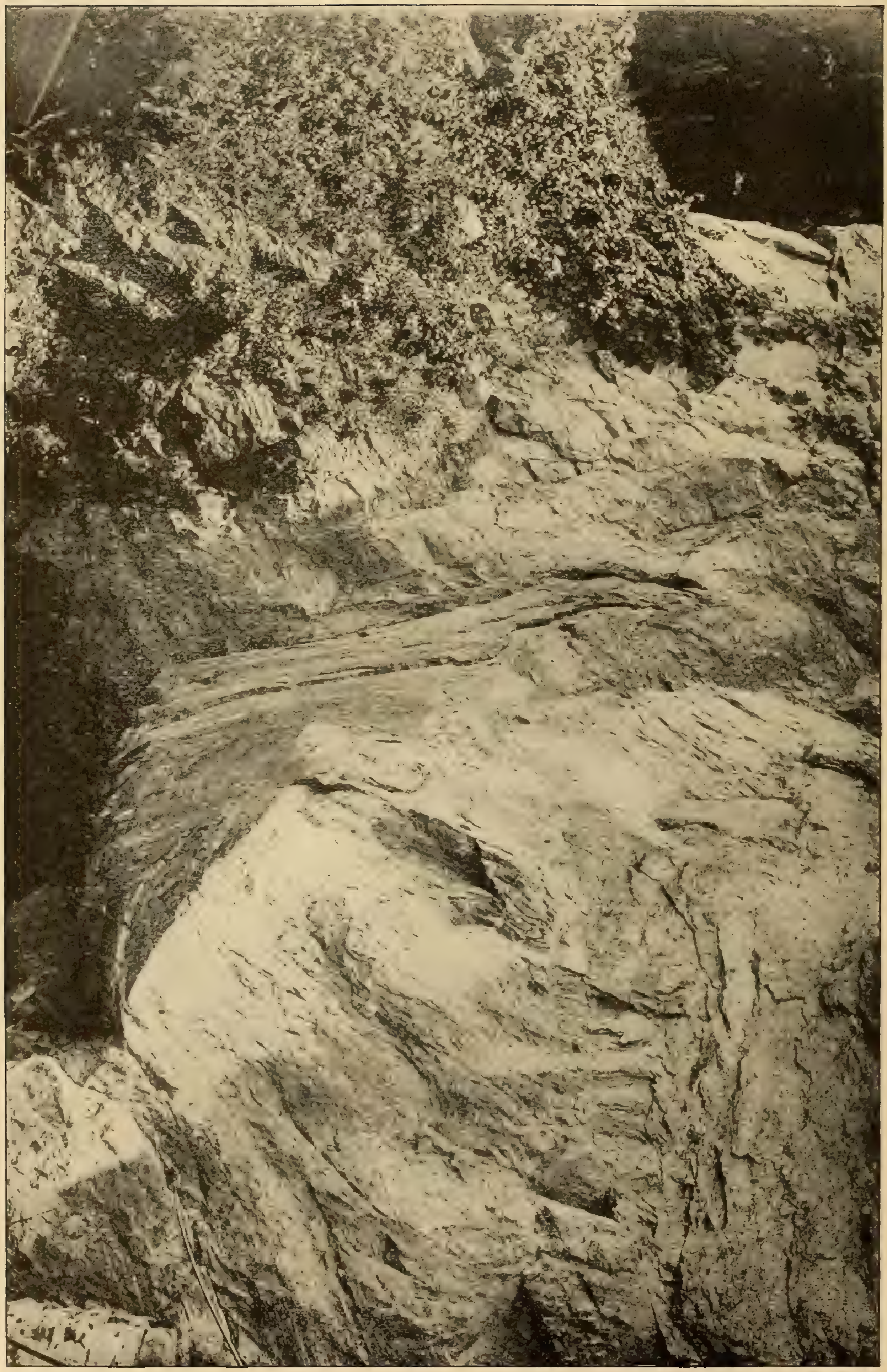
Another set of samples from the quarry of B. Turner near Wilbur gave:

Silica	7.1
Alumina	2.5
Ferric oxid	1.65
Lime	45.22
Magnesia	tr.
Carbon dioxid	39.1
	95.57

The Pentamerus limestone member of the Lower Helderberg in Ulster county, is a hard, dark blue or lead colored, massive limestone. Not infrequently it is somewhat cherty. Its hard and tough character frequently causes it to give rise to cliffs. Good exposures of this rock occur in the cliffs at Rosendale, about Port Jackson, near Eddyville and along the eastern face of the

H. Ries, photo.

Champlain clay resting against glaciated surface, of Helderberg limestone. Terry Bros. brickyard, East Kingston



H. Ries, photo. Rock at slope of Newark cement co., Rondout

limestone ridge extending from Rondout to Saugerties and West Camp. They are generally a mile or more from the shore of the Hudson, but 2 miles north of Rondout approach close to it. The Pentamerus limestone has a thickness of 30 to 40 feet.

Tentaculite limestone is generally a thin bedded, dark blue limestone and forms the base of the Helderberg series. Its thickness varies from 20 to 40 feet and is greatest about Rosendale.

Salina waterlime beds underlie the waterlime and are of considerable importance, as they include the well known cement beds. Darton says: "The usual characters of the formation are thin bedded water limestones, and the cement is of local occurrence." It is a blue black, very fine grained, massively bedded deposit, consisting of calcareous, magnesian and argillaceous materials in somewhat variable proportions.

The cement beds are extensively developed in the Rondout and Rosendale regions. They come in gradually and are attended by a thickening of the formation from its usual average of 20 to 30 feet to 40 or 50 feet. At Rondout the principal cement bed has a thickness averaging about 20 feet. It lies directly on the coralline (Niagara) limestone and is overlain by altering successions of waterlime and thin, impure cement beds. The cement horizon is not exposed far north of East Kingston, but how far it extends to the northward is not known. It is seen to thicken southward, and it attains its maximum thickness in the vicinity of Rondout, thinning out again and giving place to waterlime beds south of Wilbur. It is seen to have come up again in the Whiteport anticlinal, which brings up a great development of cement beds along its principal axis from Whiteport to Rosendale. They also come out along the western limb of the synclinal eastward. South of Rosendale the cement beds continue up the Coxing kill valley and around the point of the anticlinal by Highfalls on the Rondout creek. "Above this place it can be traced but a short distance, owing to its deep erosion and heavy drift cover in the Rondout creek valley." It reappears at Port Jackson.

There are two cement beds in the Whiteport-Rosendale region. The lower one of these averages 21 feet in thickness, and the other averages 12 feet in thickness, with an intervening member of 12 or 15 feet of waterlime beds, but these thicknesses are very variable. At High falls the upper bed is 15 feet thick, the lower bed 5 feet thick with 3 feet of intervening beds of waterlime rock. The High falls are over the thicker beds.

Darton also states that "cement may be looked for in the upper Rondout valley, from Port Jackson to Ellenville, but, owing to the absence of outcrops, this should only be regarded as a suggestion."

Around Rosendale the cement industry is developed to an enormous extent, many thousand barrels of cement being produced annually. Detailed mention of the cement manufacture is made in another chapter of the report.

Nothing more will be said in this part of the report concerning the Rosendale cement rock, as it is mentioned more fully in the chapter on natural cements.

Coralline or Niagara limestone forms a thin bed underlying the cement at Rondout. It is a dark gray limestone of variable thickness. Under the cement at Rondout it is 7 feet, but at the entrance to the Becraft limestone quarries 1 mile north of East Kingston it is only 5 inches.

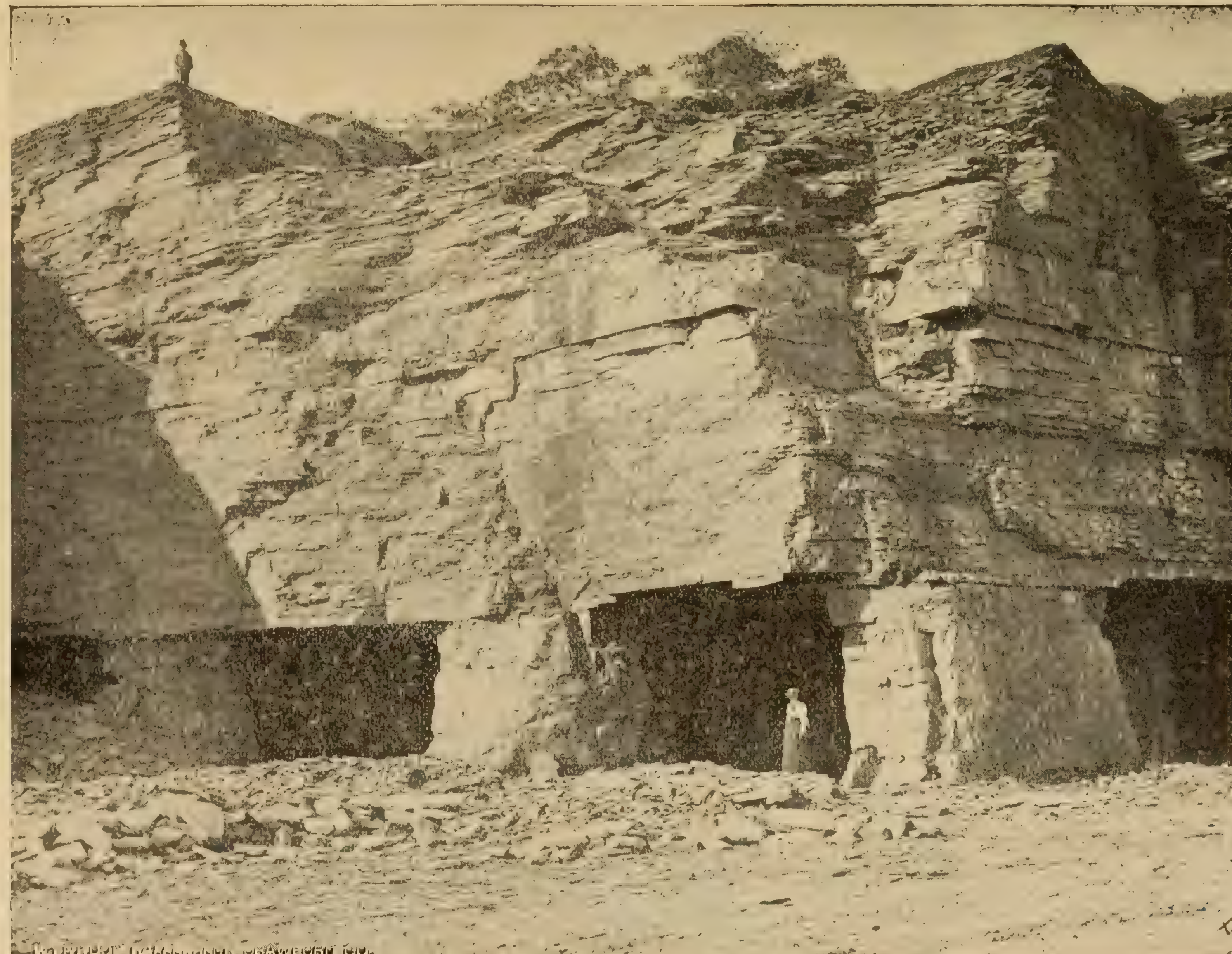
Warren county[1]

Both the Calciferous and Trenton are known in this county. The former is not of very great importance except for building purposes, but the latter is very prominent.

At Glens Falls, the Trenton limestone (pl. 72) has been quarried for a number of years for lime manufacture, and the product bears an excellent reputation. There are four companies operating lime quarries, but the rock in all of them is very much the same. The section in the quarry beginning at the top consists of:

	Feet
Thin bedded, impure black limestone	12–15
Massive black limestone	2–3
Fine grained, black, crystalline limestone	15

[1] Emmons, Ebenezer. Geol. 2d dist. N. Y. 1842. p. 170.



N. H. Darton, photo.

Quarry in Trenton limestone, Saratoga co. South bank of Hudson river opposite Glens Falls. Rock quarried for quicklime

The upper bed is used for building and also for Portland cement, being mixed with the overlying clay; the lower bed makes a high grade of lime. The following analysis represents the composition of the upper stone.

Silica	3.9
Alumina	1.3
Ferric oxid	.....
Lime	52.15
Magnesia	1.58
Sulfuric acid	.3

The composition of the lower bed is as follows:

Silica	1.1
Alumina	.8
Ferric oxid	.5
Lime	53.17
Magnesia	.75
Carbonic oxid (est.)	45.08
	101.4

The rock has to be carted three quarters to one half a mile for shipment, the distance depending on the quarry from which it is taken. The lime produced is soft but quite pure. It is said to slake rather quickly.

The analysis of the lime in the circular of the Associated lime co. is:

Lime	96.46
Magnesia	.64
Ferric oxid and alumina	1.7
Loss on ignition	1.2

An extensive Portland cement plant has been built at this locality and is described in another chapter.

Washington county[1]

The limestone areas of this county, though not extensive, include some of the purest limestones found in the state. One narrow belt extends from Middlefalls to North Argyle, a second begins at Adamsville and extends northward past the eastern edge of Fort Ann and Whitehall to the Vermont boundary. A third area lies on the boundary between New York and Vermont and along the Rutland branch of the Delaware and Hudson railroad. The rock has been extensively quarried at Smiths Basin and west of Fair Haven.

At Smiths Basin the Keenan lime company has several quarries in the ridge to the east of the railroad. The rock is mostly dark gray to bluish black, fine grained and moderately hard. Its massive character has been somewhat destroyed in places by the shearing and folding to which the rock has been subjected, and the upper beds are shaly and silicious, still the lower ones are very pure. The company has four limekilns of continuous type. Much of the rock has also been shipped to Troy both for use as a flux in blast furnaces and also for lime in Bessemer converters.

The following analyses will serve well to show the composition of the stone.

Silica	1.38
Ferric oxid and alumina	.58
Lime	55.26
Magnesia	.72
Phosphorus	.004

An analysis of the lime made by Prof. J. H. Appleton gave:

Moisture and carbon dioxid	2.08
Insoluble	1.06
Ferric oxid and alumina	.58
Lime	95.5
Magnesia	tr.
	99.22

[1] Kemp, J. F. & Newland, D. H. Preliminary report on the geology of Washington, Warren and parts of Essex and Hamilton counties. (*see* 51st an. rep't N. Y. state mus. 2: 499)
Mather, W. W. Geol. 1st dist. N. Y. 1843.

A third, made by the writer, gave:

Silica	.72
Ferric oxid and alumina	1.5
Lime	54.28
Magnesia	.8
Carbon dioxid	44
	101.3

The existence of an extensive clay deposit in the adjoining meadows offers excellent facilities for the establishment of a Portland cement plant.

A second quarry, operated by D. Nichols & Son, lies about 2 miles northeast of the preceding and is of similar purity.

Black Trenton limestone is also mined just west of the state line in Washington county. The quarry is situated along the railroad track between Whitehall and Fair Haven and is operated by George D. Harris under the name of the Arana marble co.

The rock is a dark colored, moderately hard limestone, with very few visible impurities, and in places traversed with enormous streaks of calcite, and at certain portions of the quarry, noticeably at the western end, the quarry assumes a brownish red color As a whole, it may be said that the stone is very pure, and where shale impurities occur they are generally in the shape of horses which can be easily separated in the mining of the stone. The following analysis indicates very well the high degree of purity of this material.

Silica	.7
Alumina	1
Ferric oxid	.7
Lime	53.9
Magnesia	1.4
Carbon dioxid	42.5
	100.2

The Calciferous is quarried near Whitehall, but is very silicious.

Wayne county[1]

The Niagara limestone extends through the county from west to east and is quarried at Walworth and Wolcott.

Hall[2] states that marl underlies the Cayuga marshes in the town of Savannah, and is 5 to 6 feet thick. Another bed is located one mile west of Newark, and a thin bed is formed, under Cooper's swamp, in the town of Williamson.

Westchester county[3]

The limestones in this county are all of the same age, Cambro-Silurian. They extend across the county in a northeasterly direction, forming several well marked belts which either border or underlie the main valleys. The two most important are those along the line of the New York and Harlem railroad and the Northern railroad. The former has been extensively opened up at Tuckahoe and Pleasantville, and so far as examined contains the better grade of stone. A third important area occurs south of Sing Sing (now Ossining). Other occurrences are near Somers, Amawalk and Hastings.

The limestones in this county are often highly magnesian, coarse to fine grained metamorphosed rocks. At times they are exceptionally free from silica.

There are two important quarries at Ossining, the one belonging to Henry Marks (pl. 73) the other to the Sing Sing lime co. The stone in Mr Marks's quarry is finely granular and slightly grayish in tint, while the best stone in the Sing Sing lime co.'s quarry is white and coarse grained but possesses a high degree of purity.

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1 Hall, James. (*see* Geol. 4th dist. N. Y. p. 414)

2 Geol. 4th dist. N. Y. p. 416.

3 Dana, J. D. Geological relations of the limestone belts of Westchester county, N. Y. (*see* Am. jour. sci. 1880. 20: 21, 194, 359, 450, 456; 21: 425; 22: 103, 313, 327)

Merrill, F. J. H. Geology of crystalline rocks of southeastern New York. (*see* 50th an. rep't N. Y. state mus. 2: 21)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

H. Ries, photo.

Marble quarry, Ossining, Westchester co. Metamorphosed Calciferous, Trenton limestone

A number of samples were collected from Marks's quarry, and their average composition is as follows.

Silica	.98
Ferric oxid	.3
Alumina	.84
Lime	31.4
Magnesia	16.96

This, it will be noticed, presents a high grade of magnesian limestone running very low in silica and probably suitable for the lining of Bessemer converters. There are certain layers in the quarry which have a tendency to become silicious in their character, and these have to be avoided in mining.

The rock from Marks's quarry has been shipped to Newark for a number of years to be used as flux. In this case the sorting was probably not as careful as it would have been for some purposes; and consequently the following series of analyses, kindly furnished by G. H. Stone, of the New Jersey zinc and iron co., show greater silica contents.

	1	2	3	4
Silica	6.77	5.94	5.12	2.05
Ferric oxid } Alumina }	1.81	2.82	.75	.99
				1.11
Lime	45.02	29.05	25.42	34.63
Magnesia	3.16	20.05	22.35	15.37
Phosphoric acid	.027	.....	.....	.....
Carbon dioxid	......	.....	.....	44.11

The good rock of the Sing Sing lime co. shows even less silica than that from Mark's quarry, as will be seen from the following analysis:

Silica	.87
Ferric oxid	.25
Alumina	.57
Lime	31.4
Magnesia	19.95

There are certain layers on the west side of the quarry which should be avoided, as they run more silicious. In structure these layers are thinner than those of the purer stone and more finely crystalline. Their composition was found to be as follows:

Silica	6.75
Ferric oxid	1.08
Alumina	3.02
Lime	28.32
Magnesia	17.94

The best quality of stone makes a very white lump lime.

The quarries at Tuckahoe, Westchester co., are most extensive and are all located in the same stratum, which extends northeast and southwest and has a thickness of about 40 feet. The firms operating the quarries are O'Connell & Hillery, Norcross Bros. and the Tuckahoe marble co., also known as J. Sinclair Co. The rock in all of these quarries is a magnesian limestone of granular character and moderately hard. Its character is quite constant. The beds dip steeply to the west, and those forming the walls of the quarry are very micaceous.

O'Connell & Hillery's (pl. 74) is the most southern quarry and is but a short distance from the Tuckahoe railroad station. The rock is used chiefly for making lime, but in recent years the manufacture of marble dust has also begun. The following analysis of the stone was furnished by the company.

Carbonate of lime	70.1
Carbonate of magnesia	25.4
Insoluble matter	2.4
	97.9

Two analyses have been given of the stone. No. 1 was made by Prof. P. de P. Ricketts, and no. 2 by W. F. Hillebrand.

	1	2
Insoluble	......	1.33
Lime	30.16	30.68

H. Ries, photo.

Marble quarry, Tuckahoe, Westchester co. Metamorphosed Calciferous limestone

Magnesia	21.25	20.71
Carbonic acid	47.3	46.66
Ferric oxid	.21	.21
Water	.02	.16
Silica	.24	......
Alumina	.19	......
Loss	.63	......
	100	99.75

The Tuckahoe marble co.'s quarry is ¾ of a mile to the north. The quarry is about 400 feet long and 40 feet deep, and up to the present time the stone has been used for building purposes only.

Still farther to the north about ¼ of a mile is Norcross Bros.' quarry. The rock is similar in character to the preceding but the quarry is smaller.

The quarry at Pleasantville is the largest in Westchester county. It is operated by O'Connell & Hillery, successors to the Cornell lime co. The limestone is very uniform in its character, and, on account of its white color and coarsely crystalline character, has been called "snowflake marble." Nearly the entire production of this quarry is used for the manufacture of marble dust. The composition of the rock, according to an analysis given in the 16th annual report of the United States geological survey, pt 3, p. 468, is as follows:

Lime carbonate	54.62
Magnesium carbonate	45.04
Iron carbonate	.16
Alumina	.07
Silica	.1
	99.99

This does not quite agree with an analysis made by the writer, which represents an average of the quarry as follows:

Lime carbonate	59.84
Magnesium carbonate	36.8
Alumina	.4
Ferric oxid	.25
Silica	2.31
	99.6

A small quarry was once in operation near Scarsdale, but the rock contains considerable mineral impurities.

Crystalline limestone extends up the valley of Annsville cove and Sprout brook for several miles, and is exposed at a number of places, specially along the line of the narrow gage railroad leading up to the Edison magnetite mines. The best exposure of this is in the quarry 1¾ miles west of Peekskill rock. The rock is a fine grained, grayish white stone, which seems to be the better quality toward the eastern end of the mine, where it is of a darker color. The working face exposed is over 75 feet long. The following analysis made by J. D. Irving shows the composition of the stone, and illustrates the point that far less magnesia exists in this limestone than is found in other portions of Westchester county.

Silica	2.5
Ferric oxid and alumina	1.55
Lime carbonate	81.64
Magnesium carbonate	13.5
	99.19

Other exposures of this same rock outcrop, as low ledges on the property of Mr Higgins about 2½ miles from Peekskill village. Some of these ledges show a stone of considerable purity, while in others the rock is rather micaceous.

One of the most accessible localities in Westchester county is Verplanck, where a large quarry of these pre-Cambrian limestones exists.

Yates county[1]

No beds of limestone of importance are known in this county, but marl may be found perhaps at the northern extremities of Crooked lake.

THE CEMENT INDUSTRY IN NEW YORK STATE

Two types of cement are made in New York, viz Rosendale, or natural rock cement, and Portland cement.

The former industry was the earlier established, but the latter is expanding rapidly.

Natural rock cement

The geologic position of the cement beds and their occurrence has been mentioned under "Geology of New York limestones", and in the descriptions of Ulster, Onondaga and Erie counties, specially, and the statistics have also been given. It, therefore, remains to give a brief description of the technology of the industry as carried out in this state. The general process of manufacture of natural rock cement has already been referred to (p. 678).

The localities at which the greatest development in the methods of manufacture have occurred are Rosendale, Akron and Buffalo.

Rosendale region

The cement quarries are located at Rosendale, Lawrenceville, Binnewater, Rondout and East Kingston. Owing to the great amount of rock overlying the cement bed, and its variable dips (seldom less than 25° and sometimes as much as 75° or 80°), the

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1 Hall, James. Yates county. (*see* Geol. 4th dist. N. Y. p. 458)
Wright, B. H. Notes on geology of Yates county, N. Y. (*see* 35th an. rep't N. Y. state mus. p. 195)

common method is to mine out the cement rock, leaving great pillars to support the roof (pl. 75–77). The opening along the outcrop may at times be nearly 1000 feet long. Some idea of the method of mining may be gained from the plates.

Great falls of rock sometimes occur (pl. 78) around the entrance to the abandoned workings. The bed is commonly worked down on the dip, and the slopes are sometimes 800 or 1000 feet long.

The following table gives the number of firms in this region, and other details concerning their mines, taken from F. L. Nason's report.

The method of manufacture is well illustrated by the following description of the works of the Lawrence cement co., which have a capacity of 5300 barrels a day. The rock used is taken from two beds, known as the upper or light rock and lower or dark rock. The two are mixed and broken into a suitable size for charging into the kilns. These kilns are of stone, lined with fire brick. Alternate layers of anthracite coal and cement rock are charged into the kiln, a layer of wood being placed at the bottom to light the fire when the kiln is first started.

Each day the burned material is removed from the bottom of the kiln, while fresh fuel and green rock are introduced at the top. The material drawn contains a certain amount of underburned and overburned rock, the former going back to the kiln, while the latter is thrown away. The normally burned rock is taken to the "cracker" room, where it is crushed in crackers to fragments and grains, varying from dust to hickory nut size.

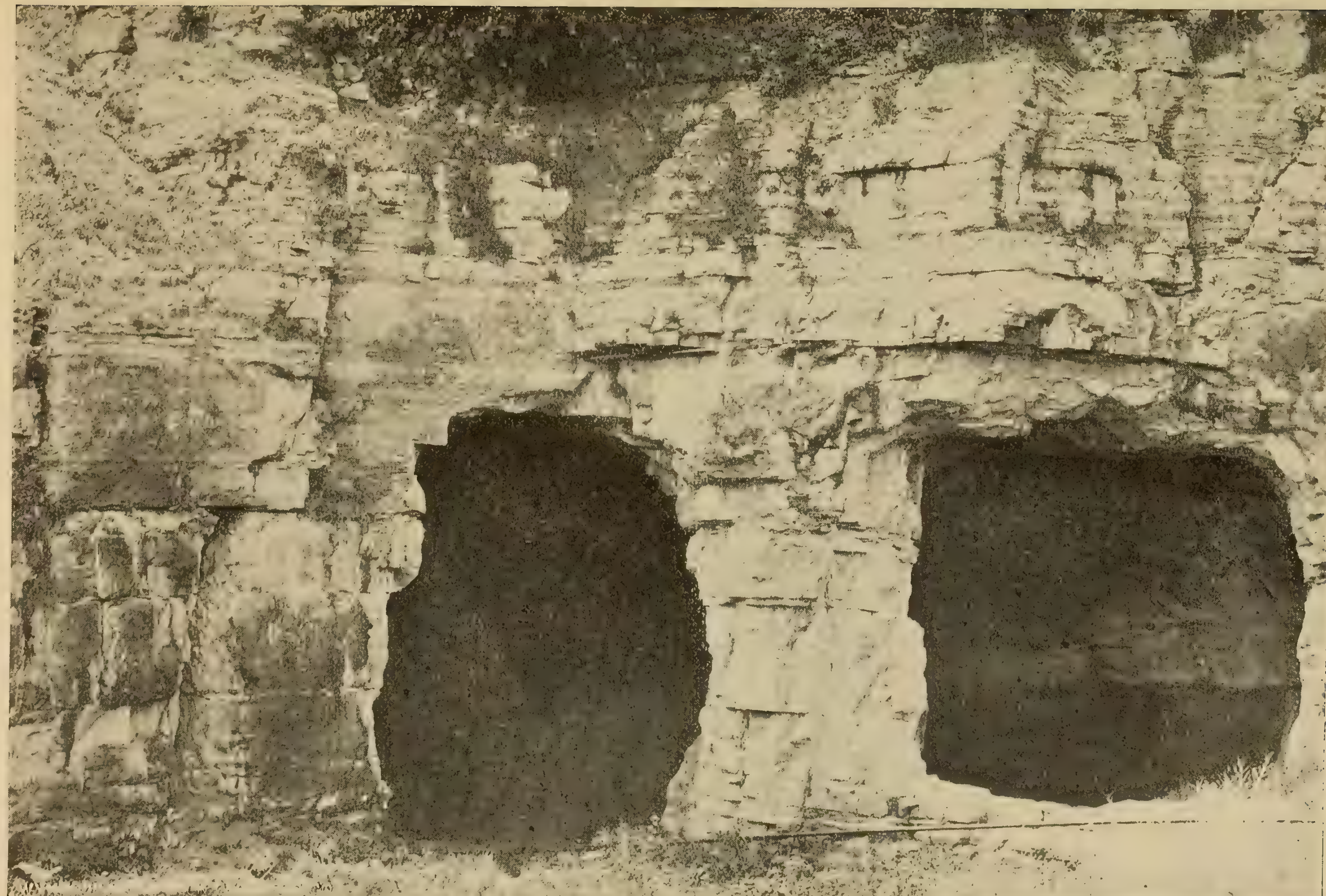
Plate 75

To face p. 834

N. H. Darton, photo.

Cement quarries, one mile south of Whiteport, Ulster co. Waterlime group

To face p. 834

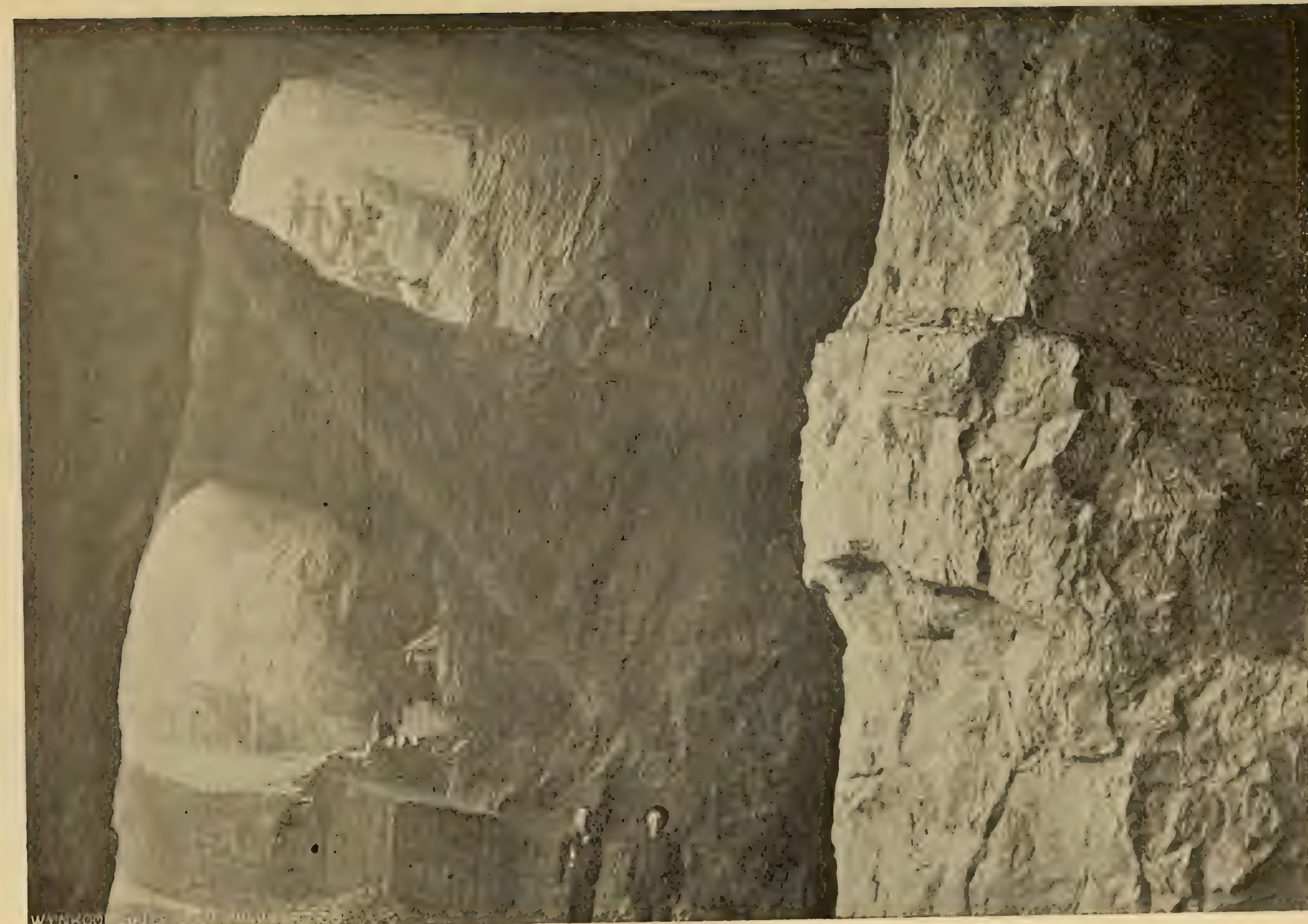


H. Ries, photo.

Old mine of the Newark cement co., Rondout, Ulster co. Waterlime group

Plate 77

To face p. 834

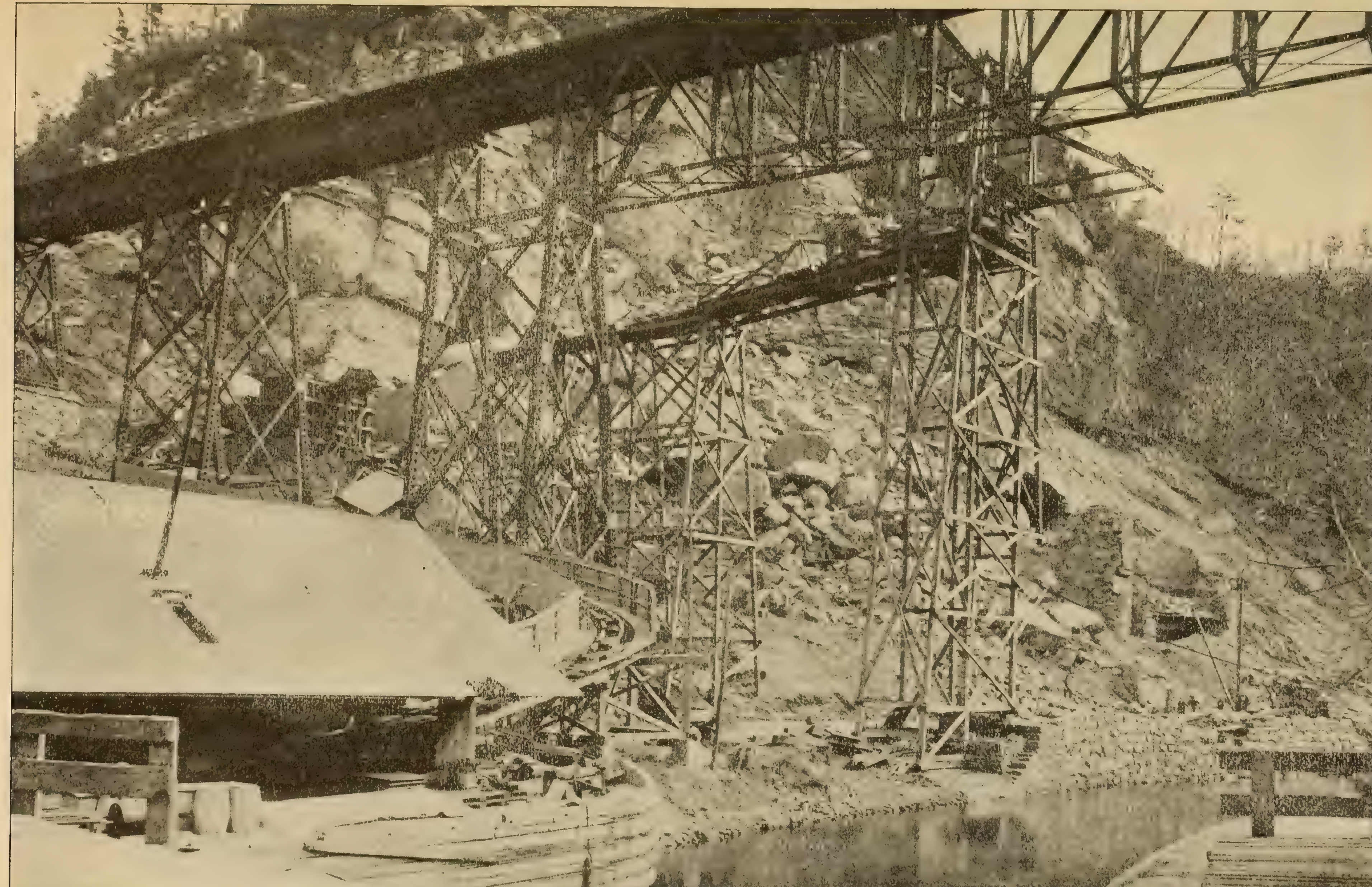


H. Ries, photo.

Interior view of cement mine at Rosendale, Ulster Co. Waterlime group

Plate 78

To face p. 834



H. Ries, photo.

Slip of rock, Rosendale

To face p. 834

H. Ries, photo.

Quarry and kilns, Lawrence cement co., at Whiteport

Cement mines of Rosendale region

MANUFACTURER	LOCATION	Depth worked measured on slope	Length of working face	Thickness of bed	Men in mines	Men on surface	Number of kilns
		Feet					
Newark lime & cement co....	Rondout	250	2000	25	70	80	21
N. Y. & Rosendale cement co..	Rosendale ...						
" ..	Wilbur......	Wilbur 150	Rosendale 525	Rosendale 33	200	130	7 large, 23 small
" ..	Quicklocks ..	Rosendale 450	....	....	......	......	....
" ..	E. Kingston.						
F. O. Norton	Highfalls	Open face	300	11	5	50	6
Highfalls & Binnewater co....	Binnewater....	300	1320	31	45	100	16
D. A. Barnhardt	Highfalls	Open face	500	32	15	33	9
J. H. Vandermark	Bunceville	"	420	30	15	18	4
Lawrenceville cement Co......	Binnewater ...	"	800	24	17	79	15
N. Y. cement co.	Lefever Falls..	450	1000	24	100	100	13
Newark & Rosendale	Whiteport	160	4000	29	55	120	17
A. J. Snyder & Son	Lawrenceville .	330	150	23	30	80	5
Connelly & Shaffer...........	Quicklocks	300	100	30	55	95	6
Lawrence cement co	Lawrencev'le						
"	Rock lock ...						
"	Eddyville ...	90–1000	60–400	11–22	171	165	64
"	Esopus						
"	Binnewater .						

These are made of cast iron, and consist of a frustum of a solid cone called the core, working concentrically within the inverted frustum of a hollow cone, both having on their adjacent surfaces suitable grooves and flanges for breaking the stone as it passes down between them. From the crackers the crushed cement is carried by means of an elevator and conveyor to a sieve 11 feet long and 10 inches wide, and about 50 meshes per inch. 25% to 27% passes this sieve. That which does not pass the sieve goes to horizontal stone mills, where it is ground between millstones, after which the two lots of fine material are mixed, and then packed in barrels for shipment.

Akron district

One of the largest plants in the state is situated at this locality, viz the Cummings cement co. (pl. 80, 81); another large works also near this town is the Union Akron cement co. (pl. 82, 83).

The Cummings cement company has 575 acres of land, and the cement bed is from 7 to 8 feet thick. The beds differ from those at Rosendale in lying almost horizontally. The kilns are 34 feet high, eight of them being of rectangular cross-section, 9x22 feet in dimensions, and nine of them round, with a diameter of 9 feet. During the calcination much of the cement rock becomes clinkered, and is separated and ground by itself to be sold as Portland cement.

At this works a general system of reduction is used, consisting of 1) Sturtevant crushers; 2) Cummings pulverizers; 3) 10 run of 42 inch underrunner millstones faced with chilled iron plates; 4) 10 run of 42 inch hard Esopus underrunner millstones.

The material, as it is conveyed from one to another of these sets of crushers, is made to pass over screens, whereby such material as has been reduced to proper fineness is separated from the mass and is spouted to a general conveyor, which finally receives the material from all the grinding machines and conveys it to the packing house. Each set of crushers, while it furnishes a part of the material, reduces the sizes of the unground portion to such a degree that the material which is fed to the fourth

To face p. 836

H. Ries, photo.

General view Cummings cement co.

Plate 81

To face p. 836

I. P. Bishop, photo.

Mine or quarry of the Cummings cement co., Akron, Erie co.

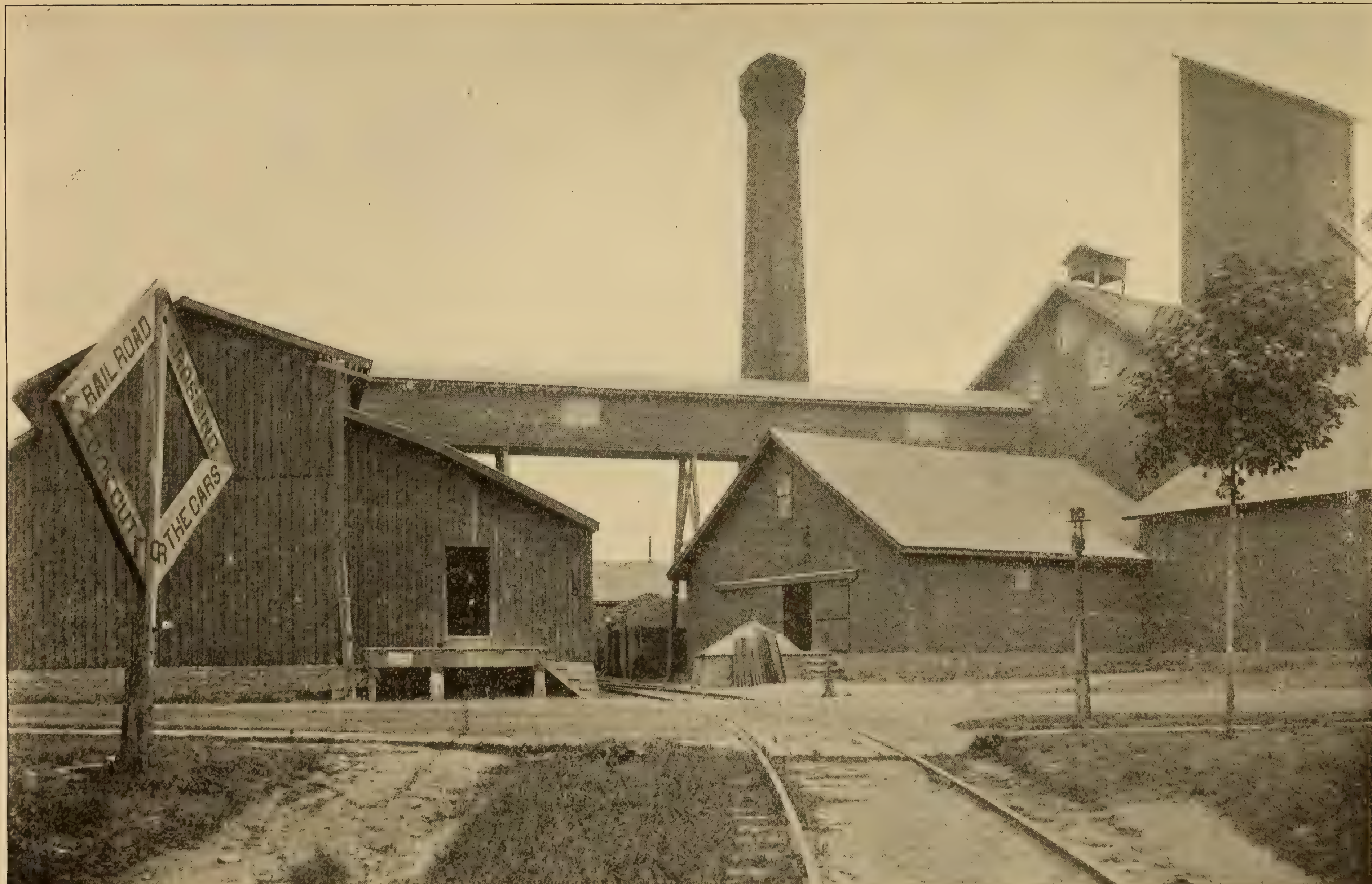
To face p. 836

H. Ries, photo.

Kilns of Union Akron cement co.

Plate 83

To face p. 836



H. Ries, photo.

Storehouse, Union Akron cement co.

Plate 84

To face p. 837

I. P. Bishop, photo.

Quarries of the Buffalo cement co., Buffalo, Erie co. Railway for drawing stone to the crusher

series is broken and worn down to the size of wheat kernels and is exceedingly hard to reduce. The harder burned portions make a cement which has a much higher tensile strength than the normally burned product.

The method of manufacture in use at the other works at Akron is somewhat similar to that employed at the plants at other localities in the state, but the kilns are in part of a more modern type, being made of sheet iron instead of stone, but, like the others, they are lined with fire brick.

The Union Akron cement co. is also contemplating the manufacture of Portland cement.

Buffalo district

The Buffalo cement co. has quarries on Main street near the belt line of the New York Central railroad (pl. 84). The cement bed underlies the Onondaga limestone. The section in its quarry shows:

	Feet
Cherty limestone	7
Massive limestone	4
Impure limestone called "bullhead"	6
Cement rock	4

The rock is burned in the ordinary stone kilns lined with fire brick, there being 10 of them, set in two rows. The rock is loaded on cars and hauled up an inclined plane to the top of the kiln, into which it is charged together with the coke that is used for fuel.

Both the normally burned and the clinkered material are fed into the grinding machinery. The first set of machines are Steadman disintegrators, and from these the material is passed over a screen, all that passes through representing the normally burned cement rock. The clinkers which are not broken fine enough by the disintegrators to pass through the screen are conveyed to a Griffin mill, where they are ground to make Portland cement. The total capacity of the plant is about 750 barrels a day.

Another cement works and quarry are located at Falkirk, and operated by H. L. & W. C. Newman, and also the Union Akron cement co.

Onondaga county

Natural rock cement, or waterlime, as it is locally called, is manufactured at a number of points in the vicinity of Syracuse. The methods of manufacture employed are similar to those in use in the Rosendale region, but the workings are all surface operations, and the cement beds are not so thick.

The following list of cement producers is taken from Luther's report, p. 271.

T. W. Sheedy. Mill and three kilns, 1 mile north of Fayetteville; quarries on Dry hill, southeast of Fayetteville.

Bangs & Gaynor. Mills and four kilns at Fayetteville; quarries on Dry hill.

J. Behan estate. Mill and four kilns, 1 mile north of Manlius.

A. E. Alvord. Nine kilns and quarries on east side of West Shore railroad at Manlius (pl. 85); mill at Syracuse.

Brown's quarry, operated by Eaton Bros. at Edwards falls, 1½ miles southwest of Manlius; mills and one kiln.

R. Dunlap, ½ mile north of Jamesville. Five kilns and mill; quarry on hill east of works.

E. B. Alvord & Co. Mill and two kilns in village of Jamesville; quarry ½ mile south of works on east side of Butternut creek.

Britton & Clark. Mill and seven kilns near Delaware, Lackawanna and Western railroad at north end of Jamesville rock cut.

L. H. Walker. Cement mill near Marcellus Falls, and quarry.

P. C. Corrigan. Mill and two kilns at Skaneateles Falls, and two quarries, one on each side of Skaneateles outlet.

[Several pages by Dr Ries on the Portland cement industry which followed here, have been replaced, at the request of the director, by the sketch of that industry given in Appendix B. This change was made at the suggestion of Dr Ries, Jan. 20, 1902.]

To face p. 838

H. Ries, photo.

Alvord & Co.'s kilns, Manlius

PRODUCERS OF LIME AND NATURAL CEMENT[1]

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Albany	Albany	Callanan road improvement co.	South Bethlehem
	Aquetuck	Carl Snyder	Coeymans
	New Baltimore	William Fuller's Sons	New Baltimore
	Ravena	Abraham Day	Coeymans
	"	W. V. D. H. Defriest	"
	"	David Hotaling	"
	"	William Hughes	"
	"	Conrad McCullock	"
Cayuga	Auburn	J. Bennett & Son	Auburn
	"	L. S. Goodrich & Son	"
	Rochester	B P. Smith	Union Springs
	Skaneateles Falls	Levi Starr	Sennet
	Union Springs	J. L. Shalebo	Springport
	"	G. P. Wood	Hamburg
Chenango	Oxford	William Lally	"
Clinton	Chazy	Chazy marble lime co.	Chazy
	"	L. M Goss	"
	Plattsburg	H. Behan	Plattsburg
	"	G. W. Pray	Peru
	"	T. Robinson	Plattsburg
Columbia	Hudson	Shute & Rightmyer	Jonesburg and Hudson
	Jonesburg	F. W. Jones	Greenport
Dutchess	Dover Plains	G. V. Bensen	Dover
	Pleasant Valley	Evert Russell	Pleasant Valley
	Poughkeepsie	F. R. Bain	Dover
	"	H. D. Hufcut	"
	"	M. Lawler	"
	Stoneco	Hud. Riv. stone sup. co.	Stoneco
Erie	Akron	H. L. & W. C. Newman	Newstead
	"	Union Akron cement co.	"
	Bellevue	B. A. Lynde	Bellevue
	Buffalo	E. J. Ambrose	Buffalo
	"	J. Armbruster	"
	"	Barber asp. pav. co.	"
	"	Buffalo cem. co., ltd.	"
	"	Consumers lime co.	Clarence
	" or Akron	Cummings cement co.	Akron
	"	Cutter & Bailey	Buffalo
	"	D. R. & H. Fogelsonger	Amherst
	"	Anna Gehres	Buffalo
	"	J. Gesl jr	"

1 For producers of Portland cement *see* Appendix B.

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Erie	Buffalo	Grattan & Jennings	Buffalo
	"	Martin Kabel	"
	"	A. P. Kehr	Clarence
	"	P. G Straub	"
	Harrishill	A. Fiegle	"
	Williamsville	J. B. & F. H. Young	Williamsville
Essex	Burlington Vt.	Burlington mfg. co.	Port Henry
	Newark N. J.	Anderson & Moynehan	Newcomb
	Willsboro Point	C. W. Frisbie	Willsboro
Fulton	Cranberry Creek	W. Kegg	Northampton
	"	Willis E. Warren	"
	Dolgeville	A. Dolge	Oppenheim
	Gloversville	Mayfield lime co.	Mayfield
	Mayfield	S. B. Warner	"
	"	Edward, Christie	"
Genesee	Batavia	A. Berthun	Batavia
	Leroy	J. H. Brown	Leroy
	"	J. Heinlich	"
	"	G. H. Holmes	"
	"	L. H. Howell	"
	"	Morris & Strobel	"
	"	Pangrazio Bros.	"
Greene	Catskill	Catskill quarry co.	Catskill
	"	G. W. Holdredge	"
	"	H. P. Palmer	"
	Climax	D. G. Haswell	Coxsackie
	Coxsackie	A. Day	"
	Smiths Landing	J. H. Gould	Catskill
	"	William Massino	"
	Urlton	J. Day	Urlton
Herkimer	Columbia	A. Manning	Columbia
	Ingram Mills	Sherman Butler	Manheim
	Little Falls	H. Jones	"
	Middleville	W. W. Mosher	Newport
	Mohawk	J. W. Humphrey	Columbia
	Newport	John Dunn	Newport
	"	Gilbert Higgins	"
	"	Newell Murray	"
	"	G. H. O'Connor	"
	"	John Sherman	"
	"	C. Smith	"
	"	Daniel Toumey	"
	North Litchfield	A. R. Davies	Litchfield
	"	Charles Dickson	"
	"	G. E. Holland	"

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Herkimer	North Litchfield	J. E. Salisbury	Litchfield
	Prospect	C. L. Talcott	Russia
	West Winfield	A. P. Bradley	Winfield
Jefferson	Cape Vincent	William Anthony	Cape Vincent
	"	R. A. Davis	"
	Chaumont	Adams & Duford	Chaumont
	"	Chaumont co.	Lyme
	Clayton	Leander Denny	Clayton
	Natural Bridge	E. & W. Hall	Wilna
	Redwood	J. McDonald	"
	Threemile Bay	J. J. Barron	Lyme
	Theresa	Loth Miller & Son	Theresa
	Watertown	H. S. Cory	Leray
	"	A. Gould	Watertown
	"	S. E. Hunting	Pamelia
	"	G. J. Lefevre	Watertown
	"	A. V. Mayhew	"
	"	P. Phillips	"?
	"	E. Williams	"?
Lewis	Collinsville	H. D. Jones	West Turin[1]
	"	M. N. Potter	"
	"	R. W. Roberts	"
	"	H. Schultz	"
	"	W. Whittlesey	"
	"	B. B. Williams	"
	Harrisville	Mary Brady	Diana
	Leyden	M. Auer	Leyden
	Lowville	William L. Babcock	L. H. Carter
	"	J. T. Campbell	"
	"	Hiram Gowdy	"
	"	M. M. Lyman	"
	"	J. Moran	"
	"	J. M. Waters	"
	Natural Bridge	F. E. Ashcraft	Diana[2]
	Lyon Falls	Orville Post	West Turin
Madison	Cazenovia	J. T. Burr	Fenner
	Chittenango Falls	C. Keeler	"
	"	C. F. Keeler & Son	"
	"	D. J Tooke	"
	"	W. M. Winchell	"
	Munnsville	F. Adams	Stockbridge
	Oneida	Mrs C. L. Faulkner	Oneida

1 Going out.
2 Closed.

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Madison	Perryville	Mrs F. W. Hodge	Sullivan
	"	C. Worlock	"
	Stockbridge	T. R. Jarvis	Stockbridge
Monroe	Rochester	Foery & Kastner	Rochester
	"	Lauer & Hagaman	"
	"	J. B. Nellis, admin.	"
	"	J. B. Pike	"
	"	Rochester lime co.	Gates
	"	Whitmore, Rauber & Vicinus	Rochester
Montgomery	Amsterdam	Amsterdam city quarry	Amsterdam
	"	J. M. Griswold	"
	"	D. C. Hewitt	"
	"	H. Stain	"
	Canajoharie	William Allen	Canajoharie
	"	G. Rapp	"
	"	A. E. & D. C. Shaper	"
	Palatine Bridge	Mohawk Valley stone co.	Palatine
	Rockton	Keating & Ritter	Rockton
	St Johnsville	Allter Bros.	St Johnsville
	"	C. Fitzer	"
	"	C. Halligar	"
	"	D. Fox	"
	"	T. Nagle	"
	"	D. Place	"
	"	A. A. Smith	"
	"	W. C. Smith	"
	Tribeshill	H. Hurst & Son	Mohawk
	"	J. G. Putnam	"
	"	J. Shanahan	"
Niagara	Buffalo	German Rock asphalt co.	Lockport
	Lockport	J. Bendiger	"
	"	M. F. Heary	"
	"	W. B. Levalley	"
	"	W. E. Lockner	"
	"	Lockport stone co.	"
	"	J. Sanders	"
	"	J. Shine	"
	"	C. H. Stainthorpe & Co.	"
	"	P. H. Tuohey	"
	"	W. H. Upson	"
	"	T. G. Watson	"
	"	C. Whitmore	"

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Niagara	Lockport	J. H. Wilson	"
	"	Woodward & Son	"
	Niagara Falls	Dean & Hoffman	Niagara
	"	B. Messing	"
	"	M. O'Rourke	"
	Wolcottville	W. J. Luckman	Royalton?
Oneida	Boonville	A. J. Lee	Boonville
	Franklin Iron Works	M. Juhl	Augusta
	Holland Patent	J. G. Hillidge	Trenton
	North Weston	J. D. Vale	Weston
	"	J. H. Van Dyke	"
	Oriskany Falls	Putnam estate	Oriskany Falls
	Prospect	E. T. Thomas	Trenton
	Sauquoit	W. W. Thurston	Paris
	Utica	E. Callahan	Trenton
	"	F. E. Conley	Oriskany Falls
Onondaga	East Onondaga	J. P. Hibbard	Onondaga
	Fayetteville	Bangs & Gaynor	Manlius
	"	H. B. Ransier	"
	"	T. W. Sheedy	"
	Hartlot	P. C. Corrigan	Elbridge
	"	A. Gorham	"
	"	C. Heavern	"
	"	J. Keenan	"
	Jamesville	E. B. Alvord & Co.	Dewitt and Lafayette
	"	R. Dunlap & Co.	Dewitt
	Manlius	A. E. Alvord	Manlius
	"	J. Behan estate	"
	"	Brown cement co.	"
	Marcellus	William Malley	"
	Marcellus Falls	L. E. Walker	Marcellus
	Onondaga Castle	Kelly Bros.	Onondaga
	"	McElroy & Son	"
	"	Storrier Bros.	"
	Splitrock	J. Connors	"
	"	C. Crowley	"
	Syracuse	Britton & Clark	"
	"	Hughes Bros.	"
	"	Kelly Bros.	"
	"	Solvay process co.	"
	"	C. Thomas	"
	"	G. Wadsworth	"

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Ontario	Canandaigua	F. McNulty	Canandaigua
	Phelps	B. Edson	Phelps
	"	W. H. Johnson	"
Orange	Johnson	House & Brown	Johnson
	Newburgh	J. J. E. Hamson	Newburgh
	"	G. W. & D. C. Miller	"
	Pine Island	C. Elston	Warwick
	Port Jervis	H. S. Whitmore	Port Jervis
	Warwick	T. Burt	Warwick
Orleans	Albion	B. Johnson	Barre
	"	T. F. Staines	"
	Clarendon	M. Murphy	Clarendon
	Shelby	E. B. Simonds	Shelby
Otsego	Cherry Valley	O. H Eldridge	Cherry Valley
	"		"
	Springfield Cent'r	W. McDonough	Springfield
Putnam	Towners	P. D. Penny	Patterson
Rockland	Tomkins Cove	Tomkins Cove stone co.	Tomkins Cove
Rensselaer	Hoosick Falls	William Carey	Hoosick Falls
	"	J. Dolin	"
	"	C. McCaffery	"
St Lawrence	Bigelow	C. Williams & Co.	DeKalb
	Brasie Corners	W. Fleming	McComb
	"	R. G. Hall	"
	Canton	E. E. Stevens	Canton
	Crary Mills	Ashley Church	Potsdam
	Gouverneur	C. A. Potter	Fowler
	"	H. J. Wright	"
	"	J. B. Abbott	Gouverneur
	"	Empire marble co.	"
	"	Gouverneur marble co.	"
	"	North. N. Y. marble co.	"
	"	St. Lawrence marble co.	"
	Hickory	V. Ingram	McComb
	"	William Perin	"
	Norwood	G. W. Hale	Potsdam
	"	J. L. Murray	"
	Ogdensburg	M. Frank & Son	
	"	J. F. Howard	Oswegatchie
	"	J. McConville	
	"	J. H. Nevin	Oswegatchie
	"	G. A. Wright	"

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Saratoga	Saratoga Springs	C. G. Slade	Greenfield
	"	I. F. Wagar	Milton
	Sandyhill	D. Sturtevant	South Glens Falls
	Saratoga Springs	M. H. Gorman	
	South Greenfield	E. Wing	Milton
Schoharie	Cobleskill	F. Baard	Cobleskill
	"	J. Brandenstein	"
	"	Cobleskill quarry co.	"
	"	William Reilly	"
	"	J. C. Rodgers	"
	"	Whalen Ross & Co.	"
	Howe Cave	Helderberg cement co.	Howe Cave
	Middleburg	A. Bishop	"
	Schoharie	C. L. Becker	Schoharie
	"	A. Brown	"
	"	E. Farquer	"
	Sharon Center	W. Crounse	Sharon Center
	Sharon Springs	F. C. Mallet	Sharon
	"	H. S. Smith	"
	"	J. Smith	"
	"	W. T. Smith	"
Seneca	Seneca Falls	J. Fisher	Fayette
	Waterloo	D. Babcock	"
	"	Edson Bros.	Waterloo
	"	G. C. Thomas & Bro.	"
Ulster	Accord	J. Bennett	Rochester
	"	G. Krom	"
	"	A. N. Longendyke	"
	"	W. H. Rose	"
	"	J. Wakeman	"
	Brooklyn	P. H. Flynn	Saugerties
	Ellenville	B. Vandermark	Wawarsing
	Kaatsbaan	W. Fiero	Saugerties
	"	L. H. Gallagher	"
	Kerhonkson	N. Christianer	Kerhonkson
	"	E. H. Jordan	Rochester
	Kingston	L. Noone	Kingston
	Mettacahonts	S. Gray	Rochester
	Napanoch	Young & Humphrey	"
	Newcomb	J. R. Sayre jr & Co.	Kingston
	New York	The Newark & Rosendale lime and cement co.	Whiteport
	Rondout	F. W. Gross	Kingston
	"	Lawrence cement co.	"

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Ulster	Rondout	Newark lime and cement mfg. co.	
	"	N. Y. and Rosendale cement co.	Rosendale
	Saugerties	P. H. Flynn	Saugerties
	Stoneridge	J. Basten	Marbletown
	"	S. Davenport	"
	Wawarsing	C. H. Hoornbeek	Wawarsing
	Whitfield	A. Barley	Rochester
	"	B. C. Dixon	" [1]
Warren	Glens Falls	Associated lime companies, including Glens Falls co.	Queensbury
	"	Jointa lime co.	"
	"	Reynolds & Reardon	"
	"	Sherman lime co. and Morgan lime co.	"
	Sandyhill	Drake & Stratton co. ltd.	"
	Thurman	J. Pellitier	Thurman
	Ticonderoga	I. Joubert	Bolton
	West Troy	G. Marks	Glens Falls
Washington	Fort Edward	G. F. Harris	Whitehall
	Greenwich	H. C. Bennett	Greenwich
	Middlefalls	H. B. Bates	"
	"	J. M. Grouty	"
	"	A. Kenyon	"
	"	J. Kipperly	"
	"	P. Sullivan	"
	Sandyhill	Monty Higly & Co.	Kingsbury
	Smiths Basin	Keenan lime co.	Smiths Basin
	"	D. Nichols & Son	Hartford
	Troy	W. D. Cheney & Son	Smiths Basin
	Whitehall	T. Adams	Whitehall
	"	J. McLaughlin	"
Wayne	Joy	William Horn	Sodus
	Lincoln	T. O. Gould	Walworth
	"	William Hanson	" ?
	Sodus Center	E. B. Mather & Co.	Sodus
	"	G. A. Munn	"
	Walworth	W. L. Hall	Walworth ?
	"	O. Munn	"
	"	J. Read	"

1 Changed.

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Wayne	Wolcott	A. Post	Butler
	"	C. J. Walker	"
Westchester	New York	O'Connell & Hillery	Tuckahoe
	"	Snowflake marble co.	Pleasantville
	Pleasantville Sta.	Cornell lime co.	Mt Pleasant
	Ossining	Henry Marks	Ossining
	"	Sing Sing lime co.	"
	Tuckahoe	N. Y. quarry co.	East Chester
	"	Norcross Bros.	"
	"	Tuckahoe marble co.	"
	"	J. S. Young	"
	Verplanck	Brown & Fleming	Verplanck

PRODUCERS OF NATURAL ROCK CEMENT

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Erie	Akron	Cummings cement co.	Akron
	Buffalo	Buffalo cement co.	Buffalo
	Falkirk	Akron cement co.	Falkirk
	"	H. L. & W. C. Newman	"
Onondaga	Fayetteville	Bangs & Gaynor	Fayetteville
	"	T. W. Sheedy	"
	Jamesville	E. B. Alvord & Co.	Jamesville
	"	R. Dunlop	"
	Manlius	A. E. Alvord	Manlius
	"	J. Behan estate	"
	"	Eaton Bros.	Edwards falls
	Marcellus Falls	L. H. Walker	Marcellus Falls
	Skaneateles	P. C. Corrigan	Skaneateles Falls
	Syracuse	Britton & Clark	Dewitt
Ulster	Binnewater	Lawrenceville co.	Binnewater
	"	High Falls & Binnewater Co.	"
	Bruceville	J. H. Vandermark	Bruceville
	Highfalls	D. A. Barnhardt	Highfalls
	"	F. O. Norton	"
	Lawrenceville	A. J. Snyder & Son	Lawrenceville
	Quicklocks	Connelly & Shaffer	Quicklocks
	Rondout	Lawrence cement co.	Binnewater
	"	Lawrence cement co.	Eddyville
	"	Lawrence cement co.	Esopus
	"	Lawrence cement co.	Lawrenceville

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Ulster	Rondout	Lawrence cement co.	Rocklock
	"	N. Y. and Rosendale cement co.	East Kingston
	"	N. Y. and Rosendale cement co.	Quicklocks
	"	N. Y. and Rosendale cement co.	Rosendale
	"	N. Y. and Rosendale cement co.	Wilbur
	"	N. Y. cement co.	Lefever Falls
	"	Newark and Rosendale cement co.	Whiteport
	"	Newark lime and cement co.	Rondout

CHAPTERS ON THE

CEMENT INDUSTRY IN NEW YORK

BY

EDWIN C. ECKEL C.E.

Appendix A

EARLY HISTORY OF THE PORTLAND CEMENT INDUSTRY IN NEW YORK STATE

BY EDWIN C. ECKEL C.E.

It seems desirable to explain, at the outset of this brief sketch of the early history of an important industry, the very slight extent to which the nominal author deserves credit for the matter submitted. This prefatory explanation is the more necessary because, for a reason stated farther on, quotation marks and separate credits have been omitted, except in a few cases; and their absence might lead the reader to the supposition that the sketch was offered as an entirely original contribution to the history of our Portland cement industry.

In the columns of *Engineering news* for May 31 and July 26, 1900, communications were published from Messrs J. Gardner Sanderson, of Scranton (Pa.) and Edward Duryee, of Colton (Cal.) Their papers, while primarily written for the purpose of clearing up certain doubtful points regarding early use of the rotary kiln in the United States, contained many interesting facts concerning the history of the Portland cement industry in New York state.

Later, while engaged in the preparation of a paper[1] describing the present condition of Portland cement manufacture in this state, I entered into correspondence with Messrs Sanderson and Duryee regarding their early experiments, intending to make use of their notes in an introduction to the paper mentioned. The material which they placed so generously at my disposal seemed, however, of too detailed and interesting a character to be used in the manner I had purposed, particularly as such use would have required that the account should be greatly condensed.

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1 Portland cement industry in New York. Eng. news. May 16, 1901

The present paper is, with the exception of a few facts which I have obtained from other sources, based entirely on the memoranda submitted by Messrs Sanderson and Duryee. Part of this material, as has been explained above, was published by them in *Engineering news.*

Quotation marks and separate credits have been generally omitted because, at least so far as the history of the Montezuma plant and the early Portland cement plants in the lower Hudson valley is concerned, the matter here submitted is merely one long set of quotations from the letters or papers of the gentlemen mentioned.

National Portland cement co., Kingston

The earliest experiments in the manufacture of Portland cement in this state, appear to have been those carried on in the Rosendale region about 1875–76. They were made by a Mr Dunderdale at East Kingston, Ulster co., Messrs Cornell and Coykendall furnishing the capital. The materials used were marl, brought by way of the Erie canal from the Montezuma marshes, and a clay obtained near the plant. Cement of a very high grade was manufactured, but the materials and processes used were of too expensive a character to permit the experiment to become a financial success. The details of the experiments are not at present obtainable, but some idea of the methods followed and of the general high quality of the product may be gained from the following, extracted from the published report, by Gen. Q. A. Gillmore, on the cements exhibited at the Philadelphia exposition of 1876.

It is deemed proper as a subject of general interest to refer briefly to some cements not represented in the exhibition.

The National Portland cement co., of Kingston, Ulster co. (N. Y.) has recently been organized for making Portland cement by the fourth method above described.[1] The materials employed

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[1] This "fourth method" here noted was, as described on a preceding page of the report, the double-kilning process, in which the calcareous material was burned and slaked before being mixed with the clay.

are fullers' earth, kaolin and lime. They are thoroughly ground and mixed together in suitable proportions by the wet process, although much less water is used than in the English works or in those at Boulogne. The mixture when completed is in a rather stiff semiliquid state. In this condition it is run out upon a floor underlaid with warming flues, where it is dried to the stiff of tempered brick clay. It is then passed through a brick machine, and subsequently burnt in common continuous upright kilns with anthracite coal.

Specimens of this cement have been tested several times by the writer with excellent results. On the last occasion the method adopted with the cements in the exhibition was strictly followed. 1½ inch cubes, seven days old, composed of equal parts of dry cement and sand, gave a crushing strength of 3335 lb. per cube, as an average of 20 trials, being a little higher than the best Portland cement exhibited, as shown by the table.

Succeeding this, in point of date, was a small plant at Low Point, Dutchess co., erected by the engineer and contractor for the first Poughkeepsie bridge. Some cement was made here, and used in the tower foundations, but the failure of the bridge project also ended the cement experiments.

Wallkill Portland cement co.

During the winter of 1877–78 Messrs J. Gardner Sanderson and T. T. Crane carried on a series of experiments at Croton on the Hudson. A small upright kiln was in use, with a Bogardus mill, and the power which, during the summer, was used in brickmaking. These experiments, and the analysis of a large number of specimens of possible materials convinced the experimenters that the Hudson river limestones generally contained too high a percentage of magnesium carbonate, and the clays too much free sand, to be suitable ingredients of a Portland cement. Certain strata of limestone, however, belonging to the Helderberg groups[1] (the outcrops of which extend approximately north and

[1] Limestone from the same horizon is now being used in the manufacture of Portland cement by two companies, the Catskill cement co. and Alsen's American Portland cement co., both plants being situated a short distance south of Catskill.

south, a short distance west of the Hudson river, crossing Rondout creek near South Rondout) were found to be remarkably pure and free from magnesia and well adapted to their purpose. As above stated, most of the clay deposits near the Hudson river carried too much sand to be of use. After careful search suitable clays were found away from the river, the best being found in an extensive deposit near Phoenicia, on the Ulster and Delaware railroad.

1880 the Wallkill Portland cement co. was organized. The limestone and clay properties above referred to were purchased, and an abandoned flour mill at Carthage Landing on the Hudson was leased and equipped with suitable machinery, a drying channel and two upright kilns. The manufacture of Portland cement was commenced at these works early in 1881. The product, though small in quantity, was of excellent quality and had a ready sale. Tests and reports by Messrs Clark and Maclay demonstrated the value of the cement, and the experimenters were satisfied that the manufacture could be made a commercial success on a larger scale. At both the Low Point and Carthage Landing plants gashouse coke was used for fuel.

Average analyses of the clay and limestone used are given later in this paper, in discussing the operations at South Rondout. A typical analysis of the cement made at Carthage Landing follows.

Lime	59.43
Magnesia	1.72
Peroxid iron	5.17
Alumina	8.13
Carbonic acid	.....
Silica	24.1
Water, alkalis, etc.	1.45
	100

In the latter part of 1881 work was commenced on a plant located on the limestone property near South Rondout, and works with a capacity of 200 to 300 barrels a day were put in operation in 1883. These works were equipped with Blake crushers, cone grinders, burstone mills, mixers, and formers. 16 upright dome kilns were in use, with a drying channel connected and heated by the waste gases from the kilns. The limestone and clay were crushed, ground and mixed dry; then steamed and formed into bricks, which were loaded on iron cars and run, by gravity, through the drying channels.

For some time after manufacture had been in progress at these works, the gas companies of New York and Albany had supplied the necessary coke for burning the material, but the introduction of the water gas process cut off this source of fuel supply. This left the plant dependent upon Pennsylvania coke, the cost of transportation and handling of which increased the cost of cement manufacture very largely. Mr Sanderson therefore commenced experiments on the use of crude Lima oil as fuel, but found that the clinkering of the cement materials in front of the burners prevented the heat from entering the charge. Knowing that this same difficulty had been met in metallurgic operations, and overcome by the use of rotary furnaces, his attention was directed toward such furnaces or kilns, as presenting a possible solution of the problem.

The kiln adopted was a form which had been patented in 1881 by Dr George Duryee, of New Jersey. In October 1888 one kiln was put into operation at the South Rondout works. This kiln was 50 feet long and 50 inches in diameter. The upper end was at first made 50 inches higher than the lower end, but later this was reduced to 30 inches. On trial this was found to be a very satisfactory method of burning, the one kiln handling all the material the mill could supply, and producing a uniform and high grade product. Of still greater importance was the fact that it was found possible to charge the mixed and ground raw

material directly to the kiln, without preliminary wetting, making into bricks and drying. This was the first American plant at which this practice of direct charging was followed.

In 1889 the plant was entirely destroyed by fire, and Portland cement manufacture in the lower Hudson valley ceased till 1900.

The following notes from the Rondout records establish some dates.

25 Oct. 1888. Burned about 100 barrels today; oil fuel. Ground the limestone and clay separately dry, and mixed before feeding to kiln. Mixture — clay 21 lb, limestone 80 lb.

25 Feb. 1889. Mixture burned — clay 21 lb, limestone 100 lb.

ANALYSIS OF RESULTING CEMENT

	Per cent
Lime	65.96
Silica	18.53
Alumina and oxid of iron	11.09
Potash	.12
Soda	.62
Carbonic acid	.97
Magnesia and undetermined	2.71
	100

PHYSICAL TESTS OF TENSILE STRENGTH

	Second tests
7 days = 253 lb	7 days = 306 lb
14 " = 466 "	10 " = 509 "

Representative analyses of the limestone and clay used at the Carthage Landing and South Rondout plants are as follows:

	Limestone Per cent	Clay Per cent
Lime	52.295	1.255
Magnesia	.5	2.37
Peroxid iron	.438	9.144
Alumina	.677	20.771
Silica	4.405	54.011
Carbonic acid	41.515	.4
Water and alkalis	.17	12.049
	100	100

Montezuma cement co.

In the fall of 1890 operations were commenced at Montezuma (N. Y.) The company owned 1700 acres of land, underlain by a deposit of marl and clay which varied in thickness from 4 to 20 feet. The deposit lay below the level of the Cayuga river and near its shores. It was overlain by several feet of muck, which was first dredged off and used for filling and grading for a railroad. The marl and clay ran pretty uniformly in composition, and it was therefore found practicable to excavate both materials by machinery. The bucket of the steam dredger employed brought up a ton every three minutes. Cars were run on the track under the bucket of the dredge to receive the material, and the loaded cars were then run on platform scales and weighed.

The marl containing about 50% water was drawn by a steam hoist up an incline into the second story of the works and above the upper end of a mixing machine, into which the load was dumped without drying or any other preliminary treatment. At the same time a weighed and ground portion of clay was added to standardize the mixture. The materials mixed as they gravitated toward the lower end of the machine. The entire process was practically continuous, a fresh charge being added at the upper end of the mixer every 10 minutes, while an equal amount was being gradually drawn off from the lower end in the same space of time. The mixture then passed to a stone mill that completed the mixing and ground any coarse materials. From the mill the mixture was introduced directly by a screw conveyor into the rotary kiln, using oil as fuel. This was unique not only in its length, 75 feet, but in having opposite its lower end a gas retort or combustion chamber. This chamber was heated by a coal fire and vaporized the oil as it was sprayed into it. The air blast also passed into this chamber, coming from a rotary fan blower.

In the first volume of *Mineral industry,* Mr W. A. Smith gives the following interesting contemporary account of this kiln.

Duryee's revolving furnace consists of a sheet-iron cylinder, 75 feet long, inclined toward the firing end $\frac{3}{8}$ inch to 1 foot. The lower hot end is 6 feet in diameter for a length of 20 feet, and is lined 9 inches thick with a mixture of ground fire brick and molasses. The remainder of the cylinder, 55 feet long, has a diameter of 5 feet, and is lined with 6 inch fire brick. Only the lining at the hot end requires renewal, and this can be replaced in 10 hours, at a cost of $25. The cylinder revolves on cast iron rollers three times a minute. The power required is five horse-power.

At the lower end a small coal fire is kept up on a grate, but the chief fuel is crude petroleum, introduced in a jet which meets the hot air blast. The consumption of oil is 8 gallons per barrel of cement clinker produced. 15 barrels of oil are required to heat the furnace ready for burning cement.

The clay and marl are mixed wet and run in as a slurry at the upper end. The mixture in drying forms a sand, which moves slowly downward with the turning of the cylinder, and is finally discharged at the lower end as cement clinker of the size of small gravel. It takes two hours to run the particles through. The operation is continuous, and the product is 250 barrels per day. It is claimed that all the mixture is burned to Portland clinker.

From a series of analyses and tests, for which I am indebted to Mr Duryee, I have selected the following:

ANALYSES OF MATERIALS USED AND RESULTING PRODUCT AT MONTEZUMA

	MARL [1]	CLAY	CEMENT
Lime	47.68	.....	62.22
Silica	6.22	59.22	22.51
Alumina	1.7	20.82	9.17
Iron oxid	.66		2.54
Magnesia	.52	3.09	1.08
Carbonic acid	42.11	.....	1.86

[1] Calculated without moisture.

A report by Mr W. W. Maclay, dated Ap. 28, 1892, gives the tensile strength obtained as

	AVERAGE
Neat, 7 days	649 lb
Mortar (1:2), 7 days	245 "
Mortar (1:2), 28 days	418 "

The works at Montezuma were entirely destroyed by fire in June 1893, and have never been rebuilt. The plant is of particular interest because of the advanced technologic methods there employed. It was the first American plant in which wet raw materials were fed, without drying or briquetting, directly into rotary kilns.

In following out the history of the above plants, which bore a certain relationship either in locality or management to each other, we have overlapped, in point of date, the beginning of the present system of New York cement plants. Commencing with dome kiln plants in the Hudson valley, we have traced the development in New York of the rotary kiln, and have seen how successful from a purely technologic point of view these pioneers in the industry were. The destruction by fire of the South Rondout and Montezuma plants, however, terminated the connection of these early experimenters with New York's cement industry, and the early history of that industry may be said to end in 1893. As early as 1886, another Portland plant had been erected, but this plant was managed by an Englishman, and the problem was attacked in an entirely different manner. The earlier plants had been aggressively original and American; the plant at Warners, with its dome kilns and wet mixing, was ultra-English. And till within the past year, the typical New York plant[1] has been one using marl and clay; mixing wet, briquetting and drying; and burning in dome kilns. The Warners Portland cement co. did indeed erect a rotary kiln plant near Warners,

[1] There was, in fact, but one exception to this rule. The Glens Falls Portland cement co. at Glens Falls, Warren co., has operated Schöfer kilns since 1894 on limestone and clay.

Onondaga co., but it was in operation only a short time, and has been shut down since 1894.

In 1900, however, two companies commenced the manufacture of Portland cement from limestone and clay, burned in rotary kilns. Descriptions of these plants, as well as a summary of the condition of the Portland cement industry in New York up to May 1901, will be found in the paper previously cited.[1] One additional plant, and less certainly two others of the same type, will commence operations during the present year.

For a detailed description of the present plants and conditions of the industry in New York, I must refer the reader to my recent paper on that subject. In the present paper it is only possible to give the following summary of those now operating.

Plants in New York in 1900

American Portland cement co. Jordan, Onondaga co. Materials, marl and clay in dome kilns. Erected 1892. Shut down during 1900. Brand, "Giant (Jordan)".

Catskill cement co. Smiths Landing, Greene co. Materials, limestone and clay in rotary kilns. Commenced shipping, July 1900, the "Catskill" brand.

Empire Portland cement co. Warners, Onondaga co. Built in 1886. Materials, marl and clay in dome kilns. Brands, "Empire" and "Flint".

Glens Falls Portland cement co. Glens Falls, Warren co. Built in 1894. Burned in August 1899. Recommenced shipping, August 1900. Materials, limestone and clay burned in Schöfer kilns. Brands, "Iron Clad" and "Victor".

Helderberg cement co. Howe Cave, Schoharie co. Began operations in 1898. Since 1900 the enlarged plant has been making extensive shipments. Materials, limestone and clay burned in rotary kilns. Brand, "Helderberg".

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[1] Eckel, E. C. Portland cement industry in New York. (*see* Eng. news. May 16, 1901) This paper has been rewritten and abbreviated, and in this form is now (Jan. 1902) presented as Appendix B.

T. Millen & Co. Wayland, Steuben co. Built in 1892. Materials, marl and clay in dome kilns. Brand, "Millen's Wayland".

Wayland Portland cement co. Wayland, Steuben co. Built in 1896. Materials, marl and clay in dome kilns. Brand, "Genesee".

Portland cement in New York during 1900-1

During the year 1900 two new plants went into operation in this state: that of the Catskill cement co. at Smiths Landing, Greene co., which began shipping the Catskill brand in July 1900, and the new Portland plant of the Helderberg cement co. at Howe Cave, Schoharie co., which commenced operations late in the year. This last company had produced small quantities of the Helderberg brand since 1898, but their manufacture of Portland on a large scale dates from the installation of the new plant. Both the corporations named use rotary kilns, and the materials in both localities are limestone and clay. The rebuilt works of the Glens Falls Portland cement co. at Glens Falls, Warren co., commenced shipping, just about a year having elapsed since their former plant was destroyed by fire. The works of the American cement co. at Jordan, Onondaga co., were shut down throughout 1900 owing to new construction at Egypt (Pa.)

In all, six plants were producers in 1900.

In the summer of 1901 the Empire Portland cement co. remodeled its works completely, installing rotary kilns.

Appendix B

MANUFACTURE OF PORTLAND CEMENT IN NEW YORK STATE

BY EDWIN C. ECKEL C.E.

The following paper was prepared at the request of the director in January 1902, when the remainder of the bulletin was in page proof. Part of its incompleteness is due to the necessity for haste in its preparation; and part to the fact that subjects which might naturally be included here had been discussed at length by Dr Ries.

The writer is indebted to the editor of *Engineering news* for permission to reprint portions of an article[1] written for that journal; and to the heads of the various cement plants in the state, who have without exception aided him in making the descriptions as complete as possible. The technology of the industry is discussed in somewhat greater detail in the paper above noted, to which the reader is referred: but advantage has been taken of the present publication to bring the descriptions up to date. As it now stands the paper is therefore a summary of the condition of the New York Portland cement industry in January 1902.

Descriptions of the plants

Alsen American Portland cement co. The plant of this company is located at West Camp, Ulster co., near that of the Catskill cement co. The materials used are limestone (from certain members of the Lower Helderberg series) and clay (Pleistocene) burned in rotary kilns. A feature of much interest in the early stages of this undertaking was the thoroughness with which ex-

[1] Eckel, E. C. Portland cement industry in New York. (*see* Eng. news, May 16, 1901) The descriptions of the various plants in the present paper are reprinted, almost verbatim, from this article, supplemented in the case of a few plants by data gathered during later visits to those plants.

ploratory work was carried on before the erection of the plant was finally decided on. Numerous diamond drill borings, and analyses of the resulting cores, satisfied the company as to the thickness and purity of the limestone.

American cement co. The plant of this company, located 2 miles east of Jordan, Onondaga co., was erected in 1892. The works were operated without any interruption till 1900, during which year they were shut down, owing to new construction by the company at Egypt (Pa.).

The materials used were marl and clay, both obtained from a marsh near the works, another bed of marl being owned by the company nearer to Jordan station. The marl is white, and the bed varies in thickness from 8 to 15 feet. It is overlain by a thin bed of muck, and underlain by a blue clay. The muck being stripped, the marl and clay were dug, and transported to the works by a wire rope way. The clay was dried and ground separately, after which it was mixed with the marl in pug mills. The resulting slurry was spread out on a drying floor, and cut into bricks. These bricks were then loaded on platform cars, dried in tunnels heated by coal fires, and fed to the kilns. 12 kilns, of the dome type, were in use, coke being used as fuel.

The clinker was reduced, first in Gates and Mosser chushers, and finally in Griffin mills. The cement was marketed as the Giant (Jordan) brand. Analyses of the raw materials and finished product, furnished by the company, follow:[1]

	Marl Per cent	Clay Per cent	Cement Per cent
SiO_2	.14	65.68	21.86
Al_2O_3	.36	24.08	7.17
Fe_2O_3			3.73
CaO	53.16	2.01	61.14
MgO	1.5	1.75	2.34
SO_3	....	.....	1.94

[1] Analysis by Booth, Garrett and Blair, 1898.

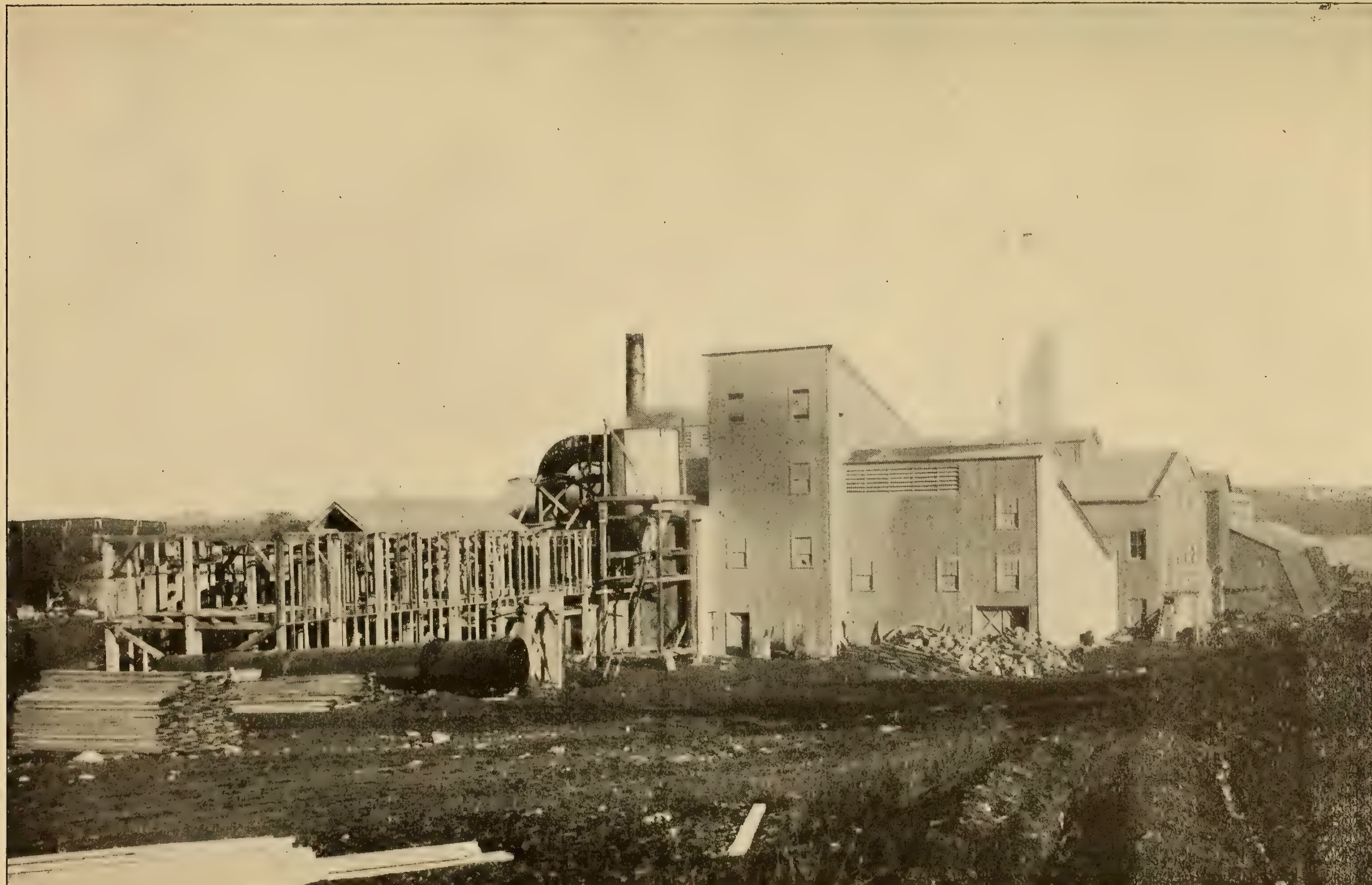
Catskill cement co. The Portland plant of the Catskill cement co., located at Smiths Landing, Greene co., was erected during 1899, and shipments were commenced in July 1900. The materials used are clay, from the river terraces, and limestone of Lower Helderberg age. A bucket cableway is used to transport the raw materials from the quarry and claybank to the works. Average analyses of these materials, furnished by the company, follow:

	Limestone per cent	Clay per cent
SiO_2	1.54	61.92
Al_2O_3	.39	16.58
Fe_2O_3	1.04	7.84
CaO	53.87	2.01
MgO	.52	1.58
Alkalis	.....	3.64
SO_3	.....	tr.

The limestone is dried and then reduced in a Krupp ball mill. The clay is passed through a roll disintegrator and is dried. The materials are, at this stage, mixed dry; and the mixing and reduction completed in Krupp tube mills. Two rotary kilns are in operation, having a total capacity of about 300 barrels a day. The clinker is crushed in Krupp ball mills, and receives its final reduction in Krupp tube mills. The cement is marketed as the "Catskill" brand. Analyses of the finished product follow. All were furnished by the company, 1 and 2 having been made in their laboratory; while 3 was made by H. E. Keifer Ph.D.

	1	2	3
SiO_2	22.48	21.94	23.44
Al_2O_3	6.52	6.02	6.35
Fe_2O_3	4.46	4.38	3.99
CaO	62.93	64.62	63.21
MgO	1.48	1.25	1.15
SO_3	1.3	1.12	1.22

To face p. 862



H. Ries, photo.

General view of works of Catskill cement co., Smiths Landing. The framework under construction is for terminal of wire rope tramway for conveying stone from quarry.

Cayuga Portland cement co. Prof. Newberry states[1] that this company "is building works near Ithaca. The material will be obtained from an outcrop of the Tully limestone and underlying shales." These underlying shales are the Moscow shales of the Hamilton group. They are rather highly calcareous, as shown by bulk analysis; but the calcium carbonate which appears in such an analysis would seem to be largely derived from the contained fossils. If this be indeed the case, extremely fine grinding and careful mixing will be necessary. The particular combination of materials to be employed at this plant is new to the state, and the operations here promise to be of much technologic interest.

Empire Portland cement co. In 1886 T. Millen & Sons commenced the manufacture of Portland cement at Warners, Onondaga co. In 1890 the plant was purchased by the Empire Portland cement co. and the works were almost entirely rebuilt, a much larger output being secured by the improvements then introduced. Since that date the plant has been in constant operation, with the exception of stops aggregating only some five or six weeks in all, caused by fires.

The materials used are marl and clay, obtained from a swamp in the vicinity of Warners, the present workings being located about ¾ of a mile from the works.

The marl bed covers an area of several hundred acres, of which about 100 acres have already been excavated.

A revolving derrick with clam-shell bucket is employed for excavating the marl, the clay being dug by hand.

The materials are taken to the works over a narrow gage railway owned by the company, on cars carrying from three to five tons each, drawn by a small locomotive.

At the works the cars are hauled up an inclined track by means of a cable and drum to the mixing floor.

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1 22d an. rep't director U. S. geol. sur. pt 6, cont'd. Issued as a separate, 1901.

The swamp from which the raw materials are obtained shows sections, from top to bottom, approximately as follows:

Material	Thickness in feet	
Muck	1	2
Upper bed white marl	4	7
Lower bed gray to brown marl	4	7
Sand	0	1
Bluish clay	2	5

As might be expected from the relative color of the marls, the material from the lower bed shows, on analysis, more organic matter than that from the upper bed, for which reason more of it must be used, with the same amount of clay, than of marl from the upper bed. This distinction is accompanied by other slight but rather constant differences in chemical composition, which have also to be taken into account in the preparation of the cement mixture.

Analyses of the raw materials follow. Those marked 1 and 3 are quoted by Cummings,[1] while 2 and 4 were recently furnished me by the company:

	Marl		Clay	
	1	2	3	4
SiO_2	.26	.26	40.48	42.85
Al_2O_3	.1	.21	20.95	13.51
Fe_2O_3		.01		4.49
$Ca\,CO_3$	94.39	91.03	25.8	22.66
$Mg\,CO_3$	.38	.4	.99	6.92
K_2O	.....	.....	3.14	3.08
SO_3	.....	.....	.....	2.85
Organic	1.54	1.68	8.5	.....
Water + loss	3.1	6.3		

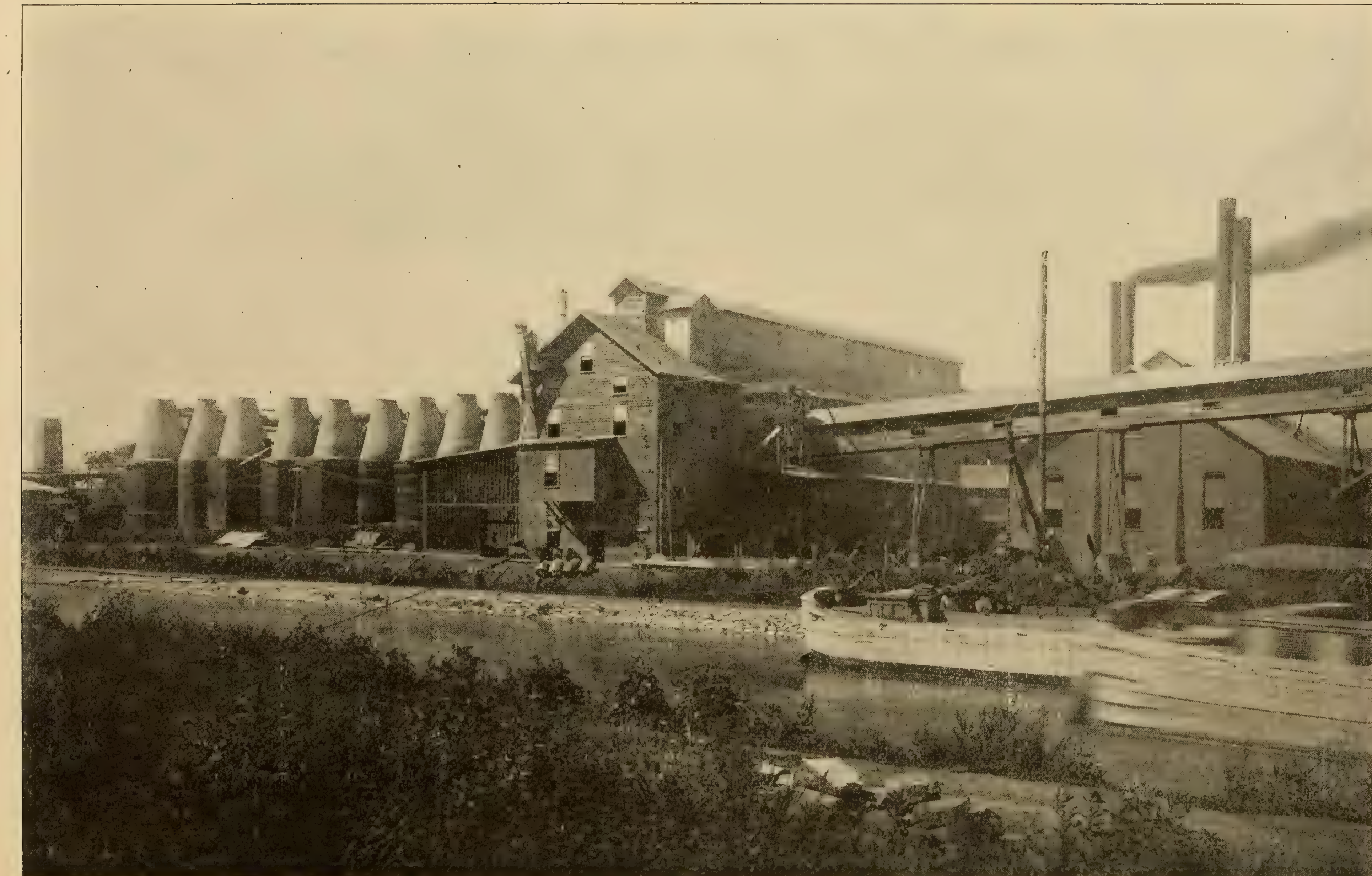
It will be noted that the clay used here runs higher in lime than does any other used in the state, the nearest approach to the above analyses being shown by that of the clay used at Wayland, which carries a little less than 20% of lime carbonate.

1 American cements, p. 253.

H. Ries, photo.

Marl bed at Warners

To face p. 865



H. Ries. photo.

Old plant of Empire Portland cement co., Warners

As noted below, rotary kilns were installed by this company during 1901, and in consequence changes have been made in the methods of preparation of the materials. The processes formerly followed are given here, as being good examples of high-grade practice at a dome kiln plant.

The clay was dried in Cummer "Salamander" dryers, three being in use, after which it was carried by conveyors to the mills, being cooled before grinding. These mills were of the Sturtevant "rock emery" type, and reduce the clay to a fine powder, in which condition it is fed to the mixer after weighing. The marl was sent directly to the mixing machine, no preliminary treatment being necessary. The marl and clay were weighed, to secure proper proportions. The relative amounts used varied, of course with changes in the chemical composition of the materials, the average charge being about 25% clay and 75% marl.

The mixing was carried on in a mixing pan 12 feet in diameter, in which two large rolls, each about 5 feet in diameter, with 16 inch face, ground and mixed the materials thoroughly. The mixture was sampled and tested, after which it passed, on a belt conveyor, to two pug mills, where the mixing was completed and the slurry was formed into bricks about 3 feet long and 5 inches diameter. These bricks were placed on slats, which were loaded on to rack cars, and run into the drying tunnels. These tunnels were heated by waste gases from the kilns, and required 24 to 36 hours to dry the bricks.

After drying, the bricks were fed to the kilns, which were charged with alternate layers of coke and cement mixture. 20 kilns, all of the dome type, were in use. The coke charge for a kiln was about four to five tons, and 20 to 26 tons of clinker were produced for each kiln at each burning. From 36 to 48 hours were required for burning the charge. After cooling the cement clinker was shovelled out, and sent to the reducing department. It received its first reduction in a Blake crusher. From this it passed to Smidth ball mills, three of which were

in operation. The final grinding was accomplished with Davidsen tube mills, two being in use.

The cement manufactured by this company was marked as the "Empire" and "Flint" brands. The superintendent of the company stated that the difference between the two brands lies in the fact that the Empire was made from specially selected clean clinker, while in the case of Flint no selection was made, the whole product of the kiln being allowed to go to the grinding machinery.

Analyses of the Empire brand follow: 1 is quoted by Cummings,[1] 2 by Lewis,[2] while 3 was furnished directly by the company:

	1	2	3
SiO_2	20.8	22.04	21.98
Al_2O_3	7.39	6.45	8.2
Fe_2O_3	2.61	3.41	3.7
CaO	64	60.92	61.83
MgO	.....	3.53	1.43
Alkalis	.....	.....	.84
SO_3	.....	2.73	1.18

During 1901 this plant was entirely remodeled, the new machinery being installed by the Bonnot co., of Canton (O.). Five 6 x 60 foot rotary kilns are now in use, each kiln being equipped with a separate feed pump. The materials are prepared for burning by passing through pug mills, emery mills, settling vats, tube mills and storage tanks, from which last the slurry goes to the rotaries. The fuel used is coal, powdered in a Raymond pulverizer. A detailed description of the new plant will be given, in the near future, in a technical journal.

Glens Falls Portland cement co. In 1893 this company commenced the erection of a plant at Glens Falls, Warren co., and their cement was put on the market in 1894, as the Iron Clad brand. Six shaft kilns of the Schöfer type were installed, the

1 American cements, p. 36.
2 Min. ind. 6: 99.

Glens Falls plant being therefore the second in this country to make use of this type of kiln. Though highly economical in fuel, the kiln is rather expensive in both the quantity and quality of manual labor required to operate it properly. A fire in August 1899, destroyed the plant, which was rebuilt to give a nominal capacity of 500 barrels a day, and the manufacture of cement was recommenced in August 1900.

The materials used are limestone and clay. The former is of Trenton age, and is obtained from the Glens Falls quarries. Considerable care is required in the selection and mixing of the stone from the various layers, in order to obtain a suitable and uniform product. A very clean and uniform clay, found overlying the limestone in this area, is the other ingredient. Analyses[1] of these materials follow:

	Limestone	Clay
SiO_2	3.3	55.27
Al_2O_3, Fe_2O_3	1.3	28.15
CaO	52.15	5.84
MgO	1.58	2.25
SO_3	.3	.12
CO_2	40.98	.....
Organic and water	8.37	.....

The limestone and clay are separately dried, and crushed in Blake crushers and rolls. After being weighed on automatic scales, the materials are mixed dry and reduced to a fine powder in Griffin mills. The powder is then fed into wet mixers, where sufficient water is added to allow its being made up into bricks. These are dried in tunnels, heated by waste heat (from the boiler) driven through the tunnel system by blowers.

After drying, the bricks are burned in Schöfer kilns, using coal as fuel. The clinker is passed first through Smidth ball mills, and finally reduced in Davidsen tube mills.

[1] Lewis, F. H. Min. ind. 6: 97.

An average analysis[1] of the Iron Clad brand shows:

SiO_2	21.5
Al_2O_3 Fe_2O_3	10.5
CaO	63.5
MgO	1.8
K_2O and Na_2O	.4
SO_3	1.5

Sand cement is also manufactured at these works, and is discussed briefly later in this paper.

Helderberg cement co. The plant of this company is located at Howe Cave, Schoharie co. Quarries in the Waterlime group at this point have been long used for the manufacture of natural cement, while quarries higher up, both geologically and topographically, furnished a very pure limestone which was burned into lime.

In 1898, the Helderberg cement co. began to utilize the stone from these latter quarries in the manufacture of Portland cement. Commenced on a small scale, the industry would seem to have promised favorable results, as a much larger plant, belonging to the same company, was erected during 1900. The new plant has a nominal capacity of 1500 barrels a day. The materials used are limestone and clay.

As noted above, the limestone used for Portland cement is obtained from the old lime quarries, and the clay from a deposit in the vicinity. Smidth ball mills and Davidsen tube mills are used for crushing, reducing and mixing the materials. The wet process is employed and 12 rotary kilns are in use. The resulting clinker is ground in ball mills and tube mills, and the product is marketed as the "Helderberg" brand.

The various quarries at Howe Cave show exposures of the different formations from the Clinton up to the Pentamerus. Dr

1 Lewis, F. H. Min. ind. 6: 97.

Charles S. Prosser[1] has determined that the entire section shown consists of the following rocks, the datum being taken as the level of the Cobleskill at the suspension footbridge.

0–32 feet covered with soil.

32–56 feet green, argillaceous shales (Clinton group).

56–63 feet dark gray, massive limestones (Niagara group).

63–102 feet gray argillaceous and magnesian limestones (Waterlime group).

102–33½ feet dark blue limestone (Tentaculite group).

133½–44½ feet limestones (transitional Tentaculite Pentamerus).

144½–68 feet very massive gray limestone (Pentamerus group).

The limestone used in Portland cement manufacture is obtained from the Pentamerus and Tentaculite beds, exposed in quarries just west of the station, on the northern side of the railroad track, while the Clinton and Waterlime beds above noted are shown only in the lower quarries. Partial analyses of these upper limestones, quoted by Prosser as having been made by C. A. Schaeffer follow:

	$Si\,O_2$	$Ca\,CO_3$
Tentaculite limestone	1.48	95.75
Pentamerus limestone	4.12	93.68

Another sample analyzed by Schaeffer gave:

SiO_2	1.27
Al_2O_3, Fe_2O_3	.73
$CaCO_3$	97.24
$MgCO_3$	1.39
SO_3	tr.

As no complete analyses of the materials actually used for Portland were obtainable, I have included this analysis, as the

1 18th an. rep't N. Y. state geol. p. 67.

sample, while coming from a quarry not used for Portland cement, is evidently from similar beds, and gives a very good idea of the iron, alumina and magnesia contents of these cement rocks.

Iroquois Portland cement co. This company is erecting a plant near Caledonia, Livingston co. Marl and clay will be used, in rotary kilns. Several companies have been formed to work deposits in this vicinity, but data concerning their plans are not obtainable.

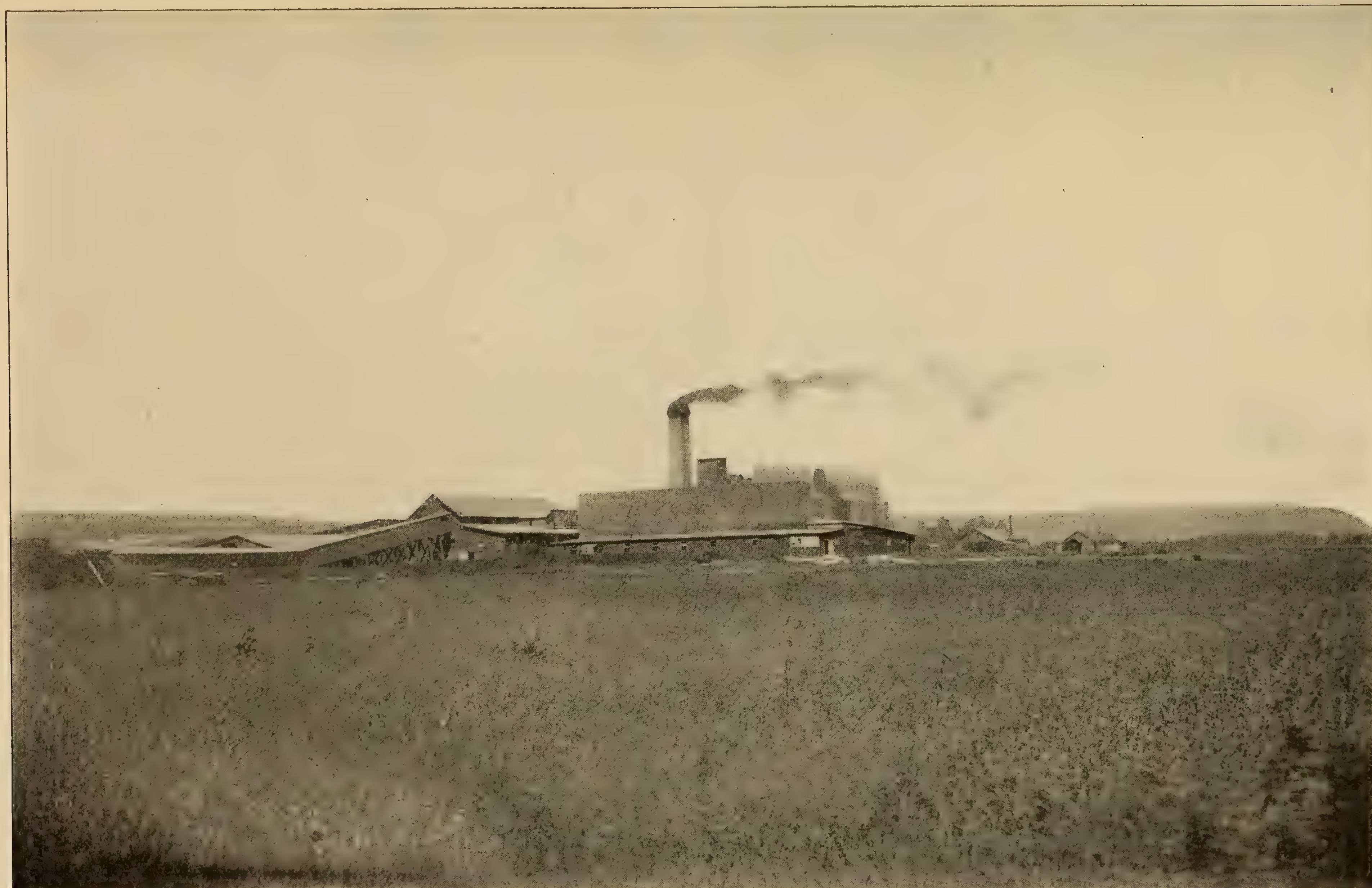
Millen's Portland cement works. After having disposed of their plant at Warners, Onondaga co., to the Empire Portland cement co., T. Millen & Co. erected their present plant at Wayland, Steuben co., which commenced producing in October 1892. The works were destroyed by fire in July 1893, but were rebuilt and began shipping again in October 1893.

The materials used are marl and clay. The marl is obtained from a swamp near the mill, about 185 acres of marsh land being owned by the company. The marl deposit is about 6 feet thick. Unlike the Onondaga county deposits, however, the marl bed is not underlain by clay, and the latter material has to be brought from a bank near Mt Morris, in Livingston county. The clay deposit there worked is one of a series which occur in the terraces bordering Canaseraga creek and the Genesee river, extending more or less continuously from Dansville nearly to Rochester. The clay for cement is worked at a point about 4 miles south of Mt Morris, and is shipped over the Delaware, Lackawanna and Western railroad to the works, a distance of about 20 miles.

The clay is dried over steam coils, ground in a Potts disintegrator and mixed with the marl in a revolving mixer. The slurry is then passed through pug mills and made into bricks. These bricks are dried in tunnels, and burned in dome kilns, 16 of which are in operation. Blake crushers, Millen crackers, and Sturtevant rock emery mills are used in the reduction of the clinker. The cement is marketed as Millen's Wayland.

Plate 89

To face p. 870



H. Ries, photo.

Plant of Millen cement co. Wayland

Analyses of the raw materials and of the finished product, furnished by the company, follow:

	Clay	Marl	Cement	
SiO_2	45.21	.42	21.08	22.19
Al_2O_3	19.08	1.08	9.56	9.72
Fe_2O_3	6.74			
$CaCO_3$	19.94	93.5	....	....
CaO	....	....	64.68	63.08
$MgCO_3$	3.27	2.13	....	....
MgO	....	....	1.85	2.04
$CaSO_4$	1.55	2.01	....	....
SO_3	....	....	1.93	1.75
Moisture and organic matter	4.17	.86	....	....
Alkalis and loss	....	....	.9	1.22

The analyses of the clinker were made for the company by Dr F.E. Engelhardt, of Syracuse (N. Y.)

Wayland Portland cement co. The plant of this company is located at Perkinsville, in the town of Wayland, Steuben co. It was erected in 1896 and has operated continuously to date.

The materials used are a light colored marl which occurs in a deposit 2–14 feet thick, overlain by 6 inches to 3 feet of muck, in a marsh near the works, and light gray (Pleistocene) clay from Mt Morris, Livingston co., for their marl deposit, like that of Millen's, is not underlain by clay. Analyses of the raw materials, furnished by the company, follow:

	Marl
Lime	54.4
Silica	.54
Fe and Al oxids	.56
MgO	2.34
Loss on ignition	42.2

	Clay
Silica	53.5
Lime	5.15
Fe and Al oxids	24.2
MgO	2.15
Loss on ignition	14.1

The clay is dried over steam pipes, broken to about ¼–½ inches size in a Potts disintegrator; and sent through a Bullock burstone mill, which grinds to about 16 mesh. It is then weighed, and mixed with the wet marl as both are shoveled into the chutes leading to the revolving mixer. The mixture then goes to the pug mills, and is made into bricks, which are sent to the drying tunnels. The lower tier of these tunnels is heated by direct heat, on the Cummer system; the upper tier by exhaust steam. 16 dome kilns are in use. From the kilns the clinker goes to an 18 x 30 inch Blake crusher; then to dry pans, receiving its final reduction in Sturtevant rock emery mills. The product is marketed as the Genesee (Wayland) brand.

Allied products

Sand cements. Two companies, under practically the same management, are at present engaged in the manufacture of sand cement. These are the Standard silica cement co., whose works at Long Island City were described in detail in *Engineering news* of April 16, 1896, and the Glens Falls Portland cement co. At the plant of this latter company, their Iron Clad cement is used, the resulting sand cement being marketed as the Victor and Adirondack brands, the latter carrying a larger proportion of sand. At the Long Island City plant the sand was first dried in Cummer dryers; then screened, mixed with the cement in the proper proportions, and ground in Davidsen tube mills.

"Natural Portlands." Two firms in New York state manufacture, in addition to their natural cements, brands which are marketed as "natural Portlands." The limestone is fed, without

H. Ries, photo.

Plant of Genesee Wayland cement co., Perkinsville

previous grinding or admixture, direct to the kilns. The resulting cement differs from a true Portland in carrying a lower proportion of lime (45%–50%) and higher magnesia (5%–10%). The cements will usually pass all Portland requirements, though not so finely ground as the normal Portlands.

Slag cements. Some time ago the Knickerbocker cement co. was organized for the purpose of making slag cement, the intention being to use the slag from the furnaces of the Poughkeepsie iron co. Operations were suspended, owing to financial difficulties not in any way connected with the cement manufacture itself; and at present no slag cement is made in this state. A brief discussion[1] of the technology of this type of cement will be found in a recent issue of *Engineering news.*

Notes on Portland cement materials

Three different combinations of materials are at present in use in New York state; while another may be utilized in the near future. Those now in use are:

1 Marl and clay

2 Limestone and clay

3 Limestone and shale

To these may be added, as of probable future use

4 Argillaceous limestone and pure limestone.

The technology of the industry has been discussed at length by Dr Ries, in the earlier portion of this bulletin; but a brief statement of the leading methods and features of the industry, as conditioned by the materials used, may be of interest.

1 **Marl and clay.** Compared with limestones, the marls are easier to excavate and easier to reduce. They contain, on the other hand, a greater proportion of organic matter and water, per ton of excavated material, than do the limestones. For this reason their transportation and handling, both between bed and mill, and in the mill itself, entail a greater expense for each barrel of finished

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[1] Eckel, E. C. Slag cement manufacture in Alabama. (*see* Eng. news. Jan. 23, 1902)

product. A marl deposit is a limited affair, though in the case of a large marsh or old lake bed the limits may be so large as to be safely disregarded. Limestone beds, on the other hand, are practically limitless, the extent to which the bed can be followed being limited only by questions of economical extraction.

Marl deposits of workable size are rare in New York state, and not all of those large enough for use are located well with regard to transportation routes. Three active plants in this state use marl and clay: two in Steuben county and one in Onondaga county. The former are at a disadvantage in respect to location, which is slightly increased by the fact that their marl beds are not underlain by clay, necessitating bringing the latter material, from some distance, by rail.

2 **Limestone and clay.** At present four New York plants are engaged in the manufacture of Portland cement from a mixture of limestone and clay. Of these, the earliest established was that of the Glens Falls Portland cement co. At this plant limestone of Trenton age is used, with a (Pleistocene) clay, burned in Schöfer kilns.

The Glens Falls plant is unique, in this state, so far as type of kiln used is concerned. The merits and defects of the Dietzsch, Schöfer and other types of improved nonrotary kilns, have been discussed in considerable detail by various authors. The fact that the Glens Falls product is of such high grade should not, of itself, be considered as an argument in favor of the Schöfer kiln, as this particular plant has always been favored as regards management. The other three plants are located at various points along the Helderberg escarpment, and use limestones derived from several different formations of the Lower Helderberg series. For purity, thickness and location (both with respect to clay banks and to great transportation routes) these limestones can hardly be equaled, and it seems certain that the center of the New York Portland cement industry will eventually be in the Hudson river valley.

3 **Limestone and shale.** The use of this combination of materials is confined, at present, to a single plant. If this plant be successful, it is probable that its example will be extensively followed, for exactly similar materials outcrop on the shores of Canandaigua, Seneca, Cayuga and other lakes of central New York. Certain technologic difficulties in the use of these materials are noted in an earlier part of this paper, and the progress of the enterprise will be followed with much interest.

4 **Argillaceous limestone and pure limestone.** This type of mixture, used so extensively in Pennsylvania and New Jersey, has not been utilized, as yet, in this state. It is practically certain that deposits of this type of material exist in at least one county of the state, but no attempt has been made to map or develop them. Prof. Spencer B. Newberry has pointed out that[1] an argillaceous limestone used with a comparatively small quantity of a purer limestone, as in the Pennsylvania and New Jersey plants, possesses one decided advantage over a limestone and clay mixture, inasmuch as less thorough mixing and fine grinding is required, for even the coarser particles of the argillaceous limestone will vary so little, in chemical composition, from the proper mixture, as to affect the result but little, should either mixing or grinding be incompletely accomplished. This argument bears against a marl and clay mixture as well as against a limestone and clay mixture, though to a less extent.

Mr F. H. Lewis has also discussed the advantages possessed by this type of material, and comes to the same decision regarding its superiority over the limestone and clay mixtures. The New York plants, however, show that it is possible to produce good Portland cement from limestone and clay; and the fact that several Pennsylvania companies are contemplating the establishment of plants in the Hudson river valley would seem to be proof that cheap cement can be made there.

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[1] Mineral resources of United States. (*see* 20th an. rep't U. S. geol. sur. 1898, pt 2, p. 545; 22d an. rep't U. S. geol. sur. 1900, pt 2.)

One of the prominent changes that has taken place recently is that in the relative number of plants using marl and using limestone. This change is shown in the following table.

		1899	1900	1901
Active plants using	marl and clay......	4	3	3
	limestone and clay..	1	3	4
	limestone and shale,	0	0	1

Another very significant feature is shown by the following table, giving the types of kiln used:

		1899	1900	1901
Active plants equipped with	dome kilns..	4	3	2
	Schöfer	1	1	1
	rotary	0	2	5

Appendix C[1]

TESTS OF CEMENT MADE BY THE STATE ENGINEER DURING 1897-1900

BY EDWIN C. ECKEL C.E.

I am indebted to Mr Edward A. Bond, state engineer, and Mr William Pierson Judson, deputy state engineer, for permission to use the data on cement tests, here briefly discussed. Mr Russell S. Greenman has kindly aided me in many ways. My thanks are also due to Mr Joseph Morje, of the New York state museum, for aid in the preparation of both manuscript and proof.

The series of cement tests tabulated and discussed were made during 1897, 1898, 1899 and 1900, in the cement testing laboratory of the state engineer's office, Albany N. Y. They are of value as they represent tests on various brands made during a comparatively long period in one laboratory. The sequence of the tests was interrupted only by one change of operators, and by one change of testing machine, both of which occurred during 1900. Mr Charles M. Pepson was in charge of the cement testing work from 1897 to July 1, 1900, when he was succeeded by Mr Russell S. Greenman, who is in charge at the present date.

As the cement samples were taken from barrels submitted for use, the results are of interest as showing the average quality of the various brands as shipped for use on actual work. The cements tested were, in general, those submitted for use on the canal improvements. A circular issued in 1899 by Mr Edward A. Bond, state engineer, offered the use of this laboratory for the testing of cements sent in by town and county officials, and some of the cement tested during 1900 came in under this offer. A number of samples have also been tested in this laboratory for Mr George L. Heins, state architect.

[1] Written in April 1901.

Specifications

The specifications under which the cements intended for use on the canal improvements were submitted, were, from 1896 to 1899, as follows.

Portland cement must be of the best quality and of such fineness that 95% of the cement will pass through a sieve of 2500 meshes to the square inch, and 90% through a sieve of 10,000 meshes to the square inch. Portland cement when mixed neat and exposed one day in air and six days in water, shall withstand a tensile strain of not less than 400 lb to the square inch; and when mixed in the ratio of 3 lb clean, sharp sand to 1 lb of cement, and exposed one day in air and six days in water, it shall withstand a tensile strain of not less than 125 lb per square inch.

Natural hydraulic cement must be of the best quality, and of such fineness that 90% will pass through a sieve of 2500 meshes to the square inch, and 80% through a sieve of 10,000 meshes to the square inch. Briquets, made of equal parts of natural hydraulic cement and crushed quartz, immersed in water as soon as they are sufficiently hard to sustain a $\frac{1}{24}$ inch wire weighted with 1 lb, must show a tensile strength of 65 lb to the square inch at the expiration of seven days; but briquets showing less than such strength will be held until 28 days have elapsed, when, if they then show such strength as to sustain as many pounds to the square inch above 125 as the seven day test shows them to have fallen below 65, they will be deemed to have passed this test.

Briquets made of neat cement must not set so as to support a $\frac{1}{12}$ inch wire with a load of $\frac{1}{4}$ lb in less than 15 minutes. Briquets of neat cement must not show checks or cracks when immersed in water for seven days after mixing.

Portland and natural cements manufactured in this state will be given the preference for this work, provided they satisfactorily pass the tests called for by these specifications.

The specifications at present in use are the following.

28 **Requirements hydraulic cement.** American Portland cement or American natural cement, as may be specified, shall be used and shall be of a brand known by prior use on extensive works to be of the best quality. Any cement not so known may be declined without testing.

29 **Storing.** Provision shall be made by the contractor for storing cement in a dry place and delivery shall not be made until the state engineer has been notified to inspect the cement and to take samples for which all facilities shall be offered by the contractor. The contractor shall replace at his own cost any cement which may be damaged while stored.

30 **Samples.** Samples will be taken by the engineer, at once on delivery, from every 10th barrel or from the equivalent of the 10th barrel, when packed in sacks, and will be numbered consecutively throughout the progress of the work; each sample shall fill a 4 inch cubical box, and each lot of samples shall be forwarded by express to Albany for separate tests, the results of which may be expected in 10 days.

31 **Tests.** These tests will follow the practice recommended by the American society of civil engineers and will be: 1st, for fineness; 2d, for soundness; 3d, for time of initial set; 4th, for tensile strength; 5th, for composition by chemical tests.

32 **Required fineness.** Cement shall be ground to such fineness that 95% by weight will pass through a standard sieve of 2500 meshes per square inch and 90% by weight will pass through a standard sieve of 10,000 meshes per square inch.

33 **Soundness.** The cement shall endure the hot water test at 125° F for 24 hours without cracking or blowing. *Chemical tests.* The state engineer may cause chemical tests of cement to be made and may reject any cement which, in his judgment, is not suited to the purpose.

34 **Initial set.** Neat cement shall not set to support $\frac{1}{4}$ lb weight on $\frac{1}{12}$ inch wire in less than 15 minutes for natural cement and 25 minutes for Portland cement.

35 **Required strength — American Portland cement.** Briquets of neat cement mixed three minutes, put in the molds with thumbs and trowel, and kept at a temperature of 65° to 70° for one day in moist air and six days in water shall show a least average tensile strength of 400 lb per square inch.

Briquets of three parts by weight of standard crushed quartz and one part by weight of Portland cement, mixed in the same manner and kept seven days under the same conditions, shall show a least average tensile strength of 125 lb per square inch.

Briquets of three parts by weight of standard crushed quartz and one part by weight of Portland cement, mixed in the same

manner and kept 28 days under the same conditions, shall show a least average tensile strength of 220 lb per square inch.

36 **Required strength — American natural cement.** Briquets of neat natural cement mixed three minutes, put in the molds with thumbs and trowel and kept at a temperature of 65° to 70° for two hours in moist air and 22 hours in water shall show a least average tensile strength of 60 lb per square inch.

Briquets of natural cement and standard crushed quartz in equal parts, by weight, mixed and handled in the same manner and kept at the same temperature for one day in moist air and six days in water, shall show a least average tensile strength of 65 lb per square inch.

Briquets similar to those last described and kept 28 days under the same conditions, shall show a least average tensile strength of 150 lb per square inch.

37 **Standard crushed quartz.** The standard crushed quartz used in the tests shall pass a sieve of 400 meshes per square inch and shall stop on a sieve of 900 meshes per square inch.

Methods of testing

In all the natural cements tested prior to July 1, 1900, the briquets were placed for two hours in air, in place of the usual 24 hours, while the neat Portlands were given a two day test for tensile strength. Since that date practice has been changed, in regard to the natural cements, to conform to the standard, while the Portlands, when tested neat, are usually given a one day test.

Crushed quartz was used in all the mortar tests on both natural and Portland cements, that have been tabulated in this paper, though in 1897 a few additional tests were made with natural sand. These have been omitted, however, as being too few in number to be of much value for comparison.

The boiling test is used on every new brand of cement submitted; and at frequent intervals on all brands.

The machine used is the Fairbanks 1000 lb automatic, with hand molded briquets. It will be noted that though a neat test is required by the specifications for Portlands, it has been made

in comparatively few cases. This is in accord with the present trend of engineering practice. It would seem desirable, however, that tests should be made with mortar briquets at longer time periods than those given. Tests at three months and a year on a few briquets from each lot would seem to be of sufficient value to pay for the extra trouble incurred in carrying them out. They would not, it is true, be of any service in deciding whether any particular lot should be accepted or not, but they would certainly give information regarding the staying qualities of each brand, which would be of use in decisions regarding future shipments of that brand.

Another test which it would seem might be profitably introduced, is the determination of the specific gravity of the cements. While there are undoubtedly good Portlands which at times fail to attain a specific gravity of 3.10, and while natural cements and slag cements may occasionally reach that figure, the test is still a good rough means of discriminating the two classes. That such a method of discrimination is not absolutely unnecessary, is shown by the fact that several brands, submitted as Portlands, behaved in a manner which made it probable that they were really natural cements, more or less carefully treated. The physical properties and methods of manufacture of such doubtful mixtures seem to be of some interest, and I hope soon to discuss them more fully in another place. I am not alluding here to the "improved" cements, made by some manufacturers of natural cements, and sold entirely on their merits, but to so called Portlands manufactured in much the same manner as the *grappier* class described by Le Chatelier.

Certain brands occasionally (and others habitually) attain in seven days a strength which enables them to pass both the seven day and 28 day requirements, even though the actual increase in strength during the additional three weeks may be slight. In some extreme cases, indeed, cements have actually shown less strength at 28 days than at seven days. Whether this condition

occurs because of methods or materials used in the actual manufacture of the cement, or, as seems certain in some cases, because of treatment after burning, it is a decided defect in the cement, and is not guarded against by the present specifications. The long time tests advocated above would go far toward preventing the acceptance of such cements, but a more direct method of attaining the same result would seem to be preferable. This might be done by changing the last two paragraphs of § 35 of the present specifications so as to read:

Briquets composed of three parts by weight of standard crushed quartz and one part of weight of Portland cement, mixed in the same manner and kept seven days under the same conditions, shall show a least average tensile strength of 125 lb per square inch.

Briquets of three parts by weight of standard crushed quartz and one part by weight of Portland cement, mixed in the same manner and kept 28 days under the same conditions, shall show a least average tensile strength which shall be at least 50% greater than that shown by briquets from the same lot, tested at seven days, and shall in no case be less than 220 lb per square inch.

Results of the tests

The results obtained during the four years noted have been tabulated in the following pages. A few tests have been omitted, where the circumstances seemed to render it advisable to take this action.

On pl. 1–12 are shown the average results obtained in the tests for fineness, time of setting, and tensile strength, the cements having been grouped according to locality. From these diagrams it will be seen that the New York Portlands have for three years out of the four given the highest results for fineness; that in tensile strength they are about on an equality with those manufactured in Pennsylvania, the product of both states averaging lower than do the two New Jersey brands; while the results shown in the tests for time of setting are the most variable.

The tests of the natural cements are of considerably less value, as they are based on a much smaller number of samples. The diagrams show very well the fine grinding practised in the Rosendale region. Pl. 94 shows the abnormally high tensile strength for cements of that class obtained during 1900 from the natural cements manufactured in Erie co., N. Y.

Portland cements 1897

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS % passing 50 mesh	FINENESS % passing 100 mesh	SET Initial	SET Hard	TENSILE STRENGTH Mortar briquets 1 cement : 3 sand Seven days	TENSILE STRENGTH Mortar briquets 1 cement : 3 sand 28 days
Alpha	Alpha N. J.	14	132	99	9[illegible] 1/8	54	132	194	307
Alsen	Hamburg, Germany	1	3	98 3/4	86 1/2	10	15	226	359
Atlas	Northampton Pa.	9	85	99	93	34	87	197	317
Columbia	Egypt Pa	3	27	100	92 1/2	39	56	160	246
Commercial	Coplay Pa	105	2 435	100	95 1/8	41	97	159	256
Dyckerhoff	Amoeneburg, Germany	1	12	100	88 3/4	94	230	185	258
Empire	Warner N. Y.	30	658	99 1/2	93 1/8	56	106	118	246
Flint	"	10	180	99 3/4	92 1/4	40	65	143	228
Genesee	Perkinsville N. Y.	6	105	99	94	33	74	141	266
Giant	Egypt Pa , Jordan N. Y.	11	94	98 7/8	92 1/4	49	87	148	248
a	Glens Falls N. Y.	9	[illegible]9	100	95	37	80	164	264
Iron Clad	"	20	299	100	94 3/4	51	122	170	274
Millen's	Wayland N. Y.	1	8	100	95	..	..	159	244
Royal Crown	....	1	1	98 3/4	90	32	61	161	214
Stettiner	Stettin, Germany	1	3	97 1/2	90	66	180	177	255
Victor *b*	Glens Falls N. Y.	5	90	100	96	35	79	198	265
Vulcanite	Vulcanite N. J.	1	5	100	96 1/4	25	48	264	379
a	Steuben co. N. Y.	38	430	99 1/8	92 3/4	57	95	158	256

a Brand not stated.
b Sand cement.

Natural cements 1897

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS % passing 50 mesh	FINENESS % passing 100 mesh	SET Initial	SET Hard	TENSILE STRENGTH Mortar briquets 1 cement : 3 sand Seven days	TENSILE STRENGTH Mortar briquets 1 cement : 3 sand 28 days
Akron natural	Akron N. Y.	4	15	95	86½	19	36	88	186
Akron Star	"	2	50	93¼	84½	40	60	103	228
Beach's	Binnewater N. Y.	19	677	94⅝	86½	36	62	75	187
Buffalo natural hydraulic	Buffalo N. Y.	2	37	88¾	78⅛	35	51	114	229
Cummings[a]	Akron N. Y.	7	110	93	81⅝	14	22	96	197
Hoffman	Binnewater N. Y.	60	1 447	94¾	87⅞	36	58	82	191
Mountain Rosendale		9	111	95	89½	33	56	81	174
Newark	Whiteport N. Y.	3	22	93½	84¾	31	52	84	189
Norton's	Binnewater N. Y.	42	917	94	86¾	34	56	83	191
Obelisk	Akron N. Y.	1	48	97½	89	16	24	86	160
Rosendale[a]	Ulster co. N. Y.	1	9	97½	92¼	40	60	66	218
Star	Fayetteville N. Y.	3	40	91¾	80½	27	40	122	263

a Brand not stated.

Portland cements 1898

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS: % passing 50 mesh	FINENESS: % passing 100 mesh	SET: Initial	SET: Hard	TENSILE STRENGTH Mortar briquets 1 cemen : 3 sand: Seven days	TENSILE STRENGTH: 28 days
Alpha	Alpha N. J.	7	72	99¾	91½	24	78	206	312
Atlas	Northampton Pa.	19	181	99½	93	31	71	191	307
Columbia	Egypt Pa.	34	477	99⅜	93½	27	61	168	248
Commercial	Coplay Pa.	61	1 009	99⅜	93¾	34	89	174	259
Egypt (Giant)	Egypt Pa.	1	3	98½	92½	25	40	169	236
Empire	Warner N. Y.	75	1 371	99¼	93⅛	34	87	148	235
Flint	"	10	103	99½	93⅝	37	86	154	262
Genesee	Perkinsville N. Y.	42	887	99⅜	93¼	37	96	178	273
Giant	Jordan N. Y.	29	323	99¾	94	39	80	161	251
Iron Clad	Glens Falls N. Y.	7	88	99⅞	94¼	27	81	189	277
Saylor's	Coplay Pa.	1	3	99	90	67	312	160	157
Star	Siegfrieds Bridge Pa.	4	52	99	93¾	.....	.....	141	218
Stettin Greston	Stettin, Germany	1	30	97½	85	58	208	192	270
Victor[a]	Glens Falls N. Y.	62	1 034	100	96	41	89	184	272
Vulcanite	Vulcanite N. J.	1	15	100	97½	30	110	187	291

[a] Sand cement.

Natural cements 1898

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS: % passing 50 mesh	FINENESS: % passing 100 mesh	SET: Initial	SET: Hard	TENSILE STRENGTH Mortar briquets 1 cement: 3 sand: Seven days	TENSILE STRENGTH Mortar briquets 1 cement: 3 sand: 28 days
Akron[a]	Akron N. Y.	2	40	92	83¾	10	26	97	233
Akron Star	"	12	370	92¼	84	16	29	95	211
Beach's	Binnewater N. Y.	7	107	96¾	88¾	31	52	75	187
Buffalo Natural Hydraulic	Buffalo N. Y.	3	105	90¾	78¾	22	46	103	237
Hoffman	Binnewater N. Y.	31	488	96¼	90	27	50	83	209
Newark	Whiteport N. Y.	1	10	98	93	20	57	....	184
Norton's	Binnewater N. Y.	9	141	96	89¾	28	49	80	199
Obelisk	Akron N. Y.	10	254	95	87¾	15	26	88	151
Rosendale[a]	Ulster co. N. Y.	2	56	95⅝	89	27	48	79	209
Union Akron	Akron N. Y.	5	193	93	8[illegible]	16	25	88	215
Union Rosendale	....	1	10	92½	86½	18	33	123	222

[a] Brand not stated.

Portland cements 1899

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS: % passing 50 mesh	FINENESS: % passing 100 mesh	SET: Initial	SET: Hard	TENSILE STRENGTH Mortar briquets 1 cement: 3 sand: Seven days	TENSILE STRENGTH Mortar briquets 1 cement: 3 sand: 28 days
Alpha	Alpha N. J	5	21	99¾	96½	113	157	215	304
Anchor Stettin	Stettin, Germany	3	13	100	98	71	156	177	241
Atlas	Northampton Pa.	10	74	99¾	96½	41	87	181	275
Columbia	Egypt Pa	10	124	99	93⅜	12	28	145	226
Empire	Warner N. Y	6	73	100	96⅝	38	93	145	241
Excelsior		1	15	100	96¾	180	260	227	350
Flint	Warner N. Y	2	18	100	99	40	62	141	224
Genesee	Perkinsville N. Y	17	115	99⅝	95½	28	51	148	243
Giant	Egypt Pa., Jordan N. Y	6	46	99¼	95½	24	55	167	264
Iron Clad	Glens Falls N. Y	10	139	100	98	45	94	207	311
Lehigh	Ormrod Pa	3	20	100	95¼	70	186	210	336
Saylor's	Coplay Pa	1	10	100	98¼	65	190	130	247
Star	Siegfrieds Bridge Pa	1	4	100	99	28	62	134	264
Victor[a]	Glens Falls N. Y	2	13	100	100	60	158	178	264

[a] Sand cement.

Natural cements 1899

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS % passing 50 mesh	FINENESS % passing 100 mesh	SET Initial	SET Hard	TENSILE STRENGTH Mortar briquets 1 cement: 3 sand Seven days	TENSILE STRENGTH 28 days
Beach's	Binnewater N. Y.	4	32	95¾	91	35	64	74	175
Brooklyn Bridge	Rosendale N. Y.	1	15	96¾	93¾	35	63	94	222
Commercial Rosendale	Coplay Pa.	1	6	92	81¾	30	45	61	131
Helderberg Rosendale	Howe Cave N. Y.	2	6	90	82	16	31	71	147
Norton's	Binnewater N. Y.	2	6	97	93½	24	38	74	173
Union Akron	Akron N. Y.	1	12	95¼	90½	30	53	86	225
Union Rosendale	....	1	15	98	91¼	5	10	146	271

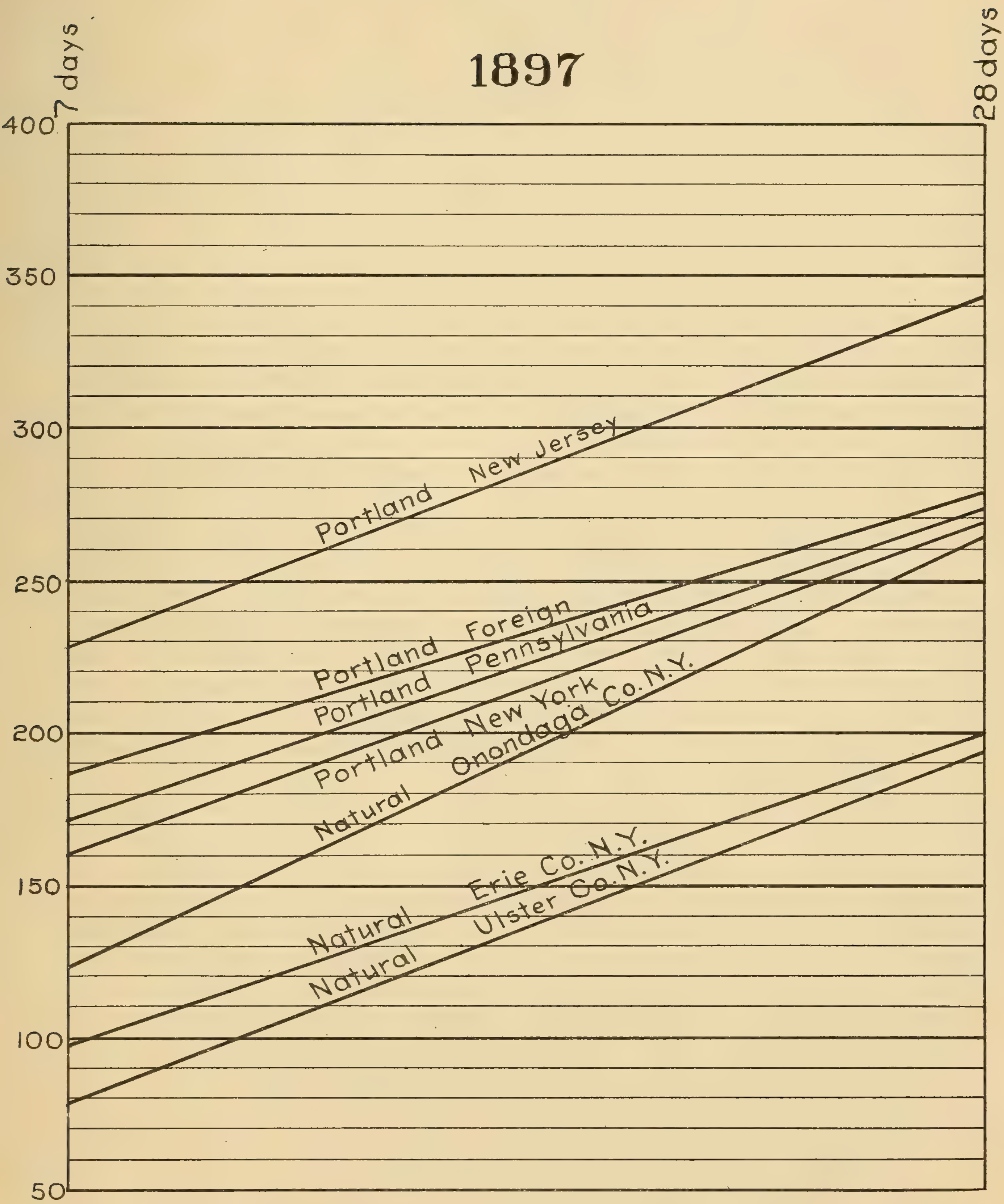
Portland cements 1900

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS		SET		TENSILE STRENGTH Mortar briquets 1 cement: 3 sand	
				% passing 50 mesh	% passing 100 mesh	Initial	Hard	Seven days	28 days
Alpha	Alpha N. J	5	28	100	97½	36	99	218	313
Ajax	....	4	9	99½	95	38	110	167	269
Atlas	Northampton Pa	19	215	99¾	95⅜	35	95	199	299
Catskill	Smiths Landing N. Y	1	6	100	98¼	25	230	183	329
Commercial	Coplay Pa	3	21	100	96	23	59	141	246
Dragon	Siegfrieds Bridge Pa	4	31	99¾	96½	83	177	263	346
Empire	Warner N. Y	4	48	99¼	95⅞	38	101	160	268
Genesee	Perkinsville N. Y	24	227	99¾	94½	31	82	163	260
Giant	Egypt Pa	6	33	99	92¾	76	150	191	315
Helderberg	Howe Cave N. Y	4	33	100	99⅞	46	87	273	392
Iron Clad	Glens Falls N. Y	3	59	100	98¾	59	145	329	358
Keystone	Coplay Pa	1	2	100	93¼	75	240	136	205
Lehigh	Ormrod Pa	7	82	99¾	94⅜	93	181	214	323
Nazareth	Nazareth Pa	2	72	100	98⅝	38	100	286	383
Paragon	....	3	14	99¾	96⅜	44	119	137	231
Vulcanite	Vulcanite N. J	8	349	99¾	95½	70	185	286	370
Whitehall	Cementon Pa	5	94	100	97¾	45	134	302	367

Natural cements 1900

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS		SET		TENSILE STRENGTH Mortar briquets 1 cement: 1 sand	
				% passing 50 mesh	% passing 100 mesh	Initial	Hard	Seven days	28 days
Akron natural	Akron N. Y.	2	16	$95\frac{1}{2}$	$84\frac{3}{8}$	24	44	169	370
Beach's	Binnewater N. Y.	1	1	$94\frac{3}{8}$	$85\frac{3}{4}$	50	75	96	210
Brooklyn Bridge	Rosendale N. Y.	2	33	$95\frac{7}{8}$	$86\frac{3}{8}$	49	85	75	189
Buffalo	Buffalo N. Y.	3	40	$99\frac{5}{8}$	92	10	15	227	413
Helderberg	Howe Cave N. Y.	10	103	$92\frac{5}{8}$	$85\frac{1}{4}$	24	43	122	240
Hoffman	Binnewater N. Y.	4	45	$97\frac{1}{2}$	92	38	70	75	211
Newark	Whiteport N. Y.	7	33	$92\frac{3}{4}$	84	30	58	67	222
New York	....	1	15	$95\frac{1}{4}$	87	50	85	70	189
Norton's	Binnewater N. Y.	3	56	97	93	44	83	71	206
Union Rosendale	....	4	34	$97\frac{5}{8}$	$92\frac{5}{8}$	10	15	104	196

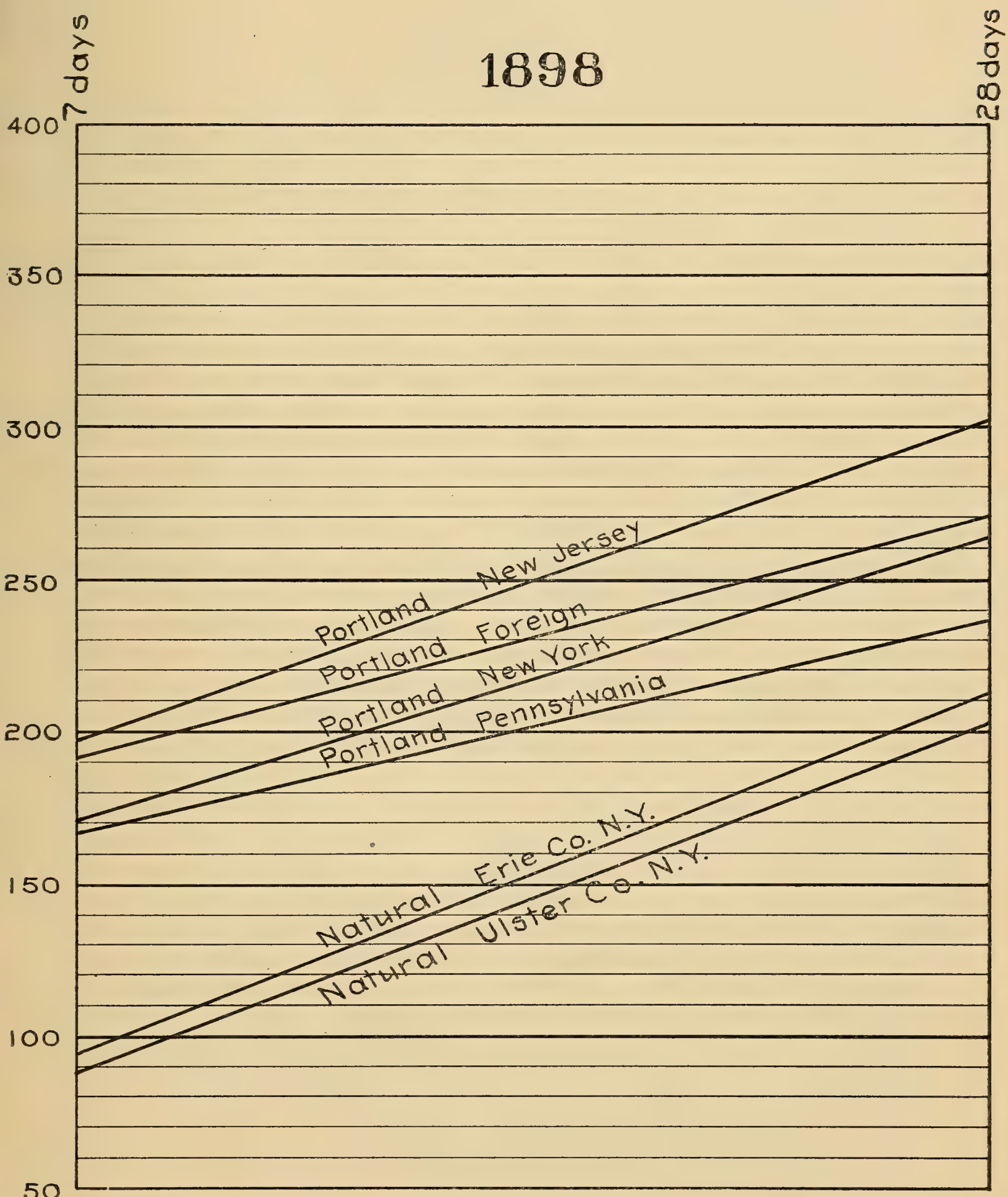
Plate 91



Tensile strength, in pounds per square inch, shown by mortar briquets
Portland briquets contain 3 sand, 1 cement.
Natural briquets contain 1 sand, 1 cement.

RESULTS OF TESTS FOR TENSILE STRENGTH

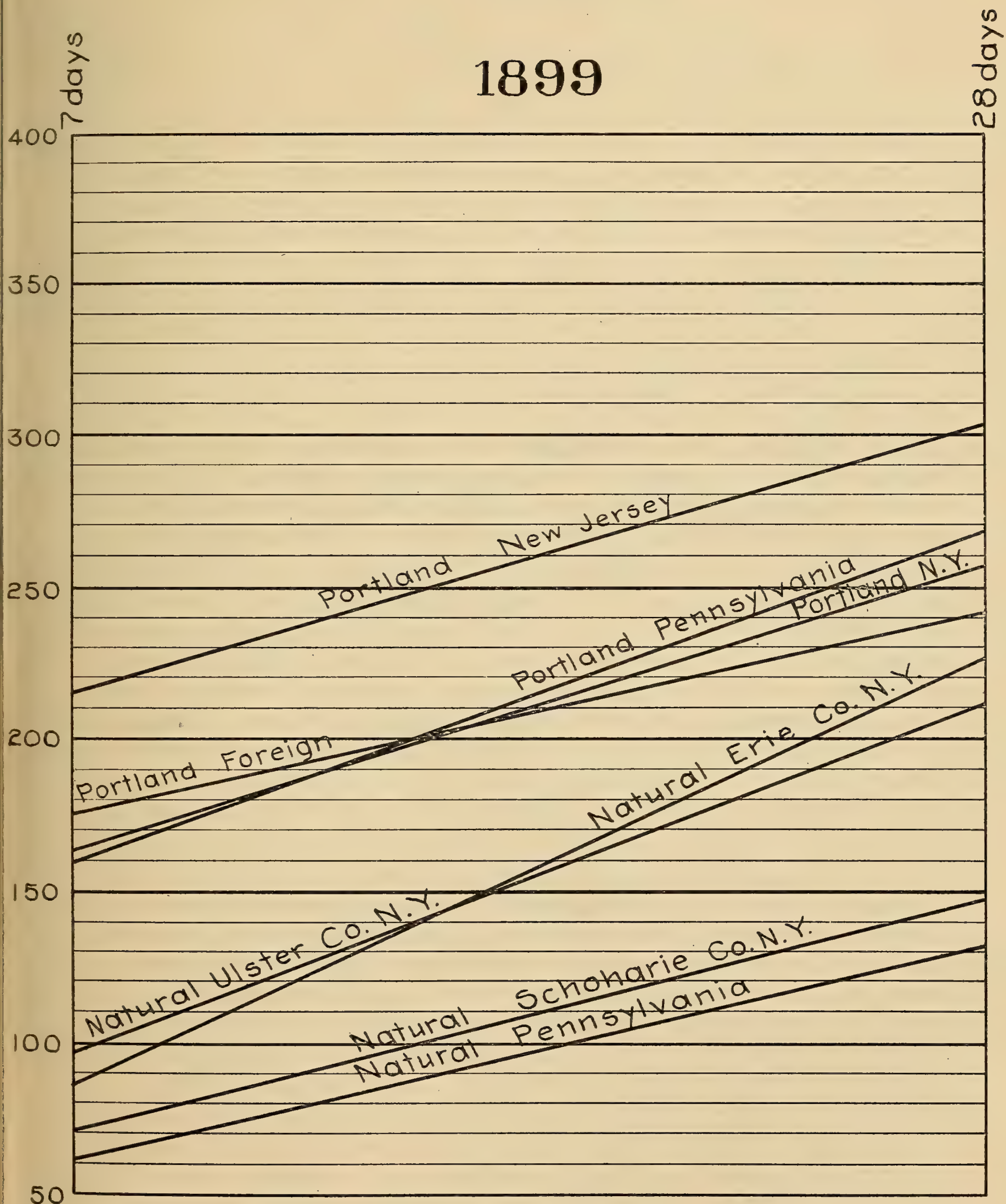
Plate 92



Tensile strength, in pounds per square inch, shown by mortar briquets
Portland briquets contain 3 sand, 1 cement.
Natural briquets contain 1 sand, 1 cement.

RESULTS OF TESTS FOR TENSILE STRENGTH

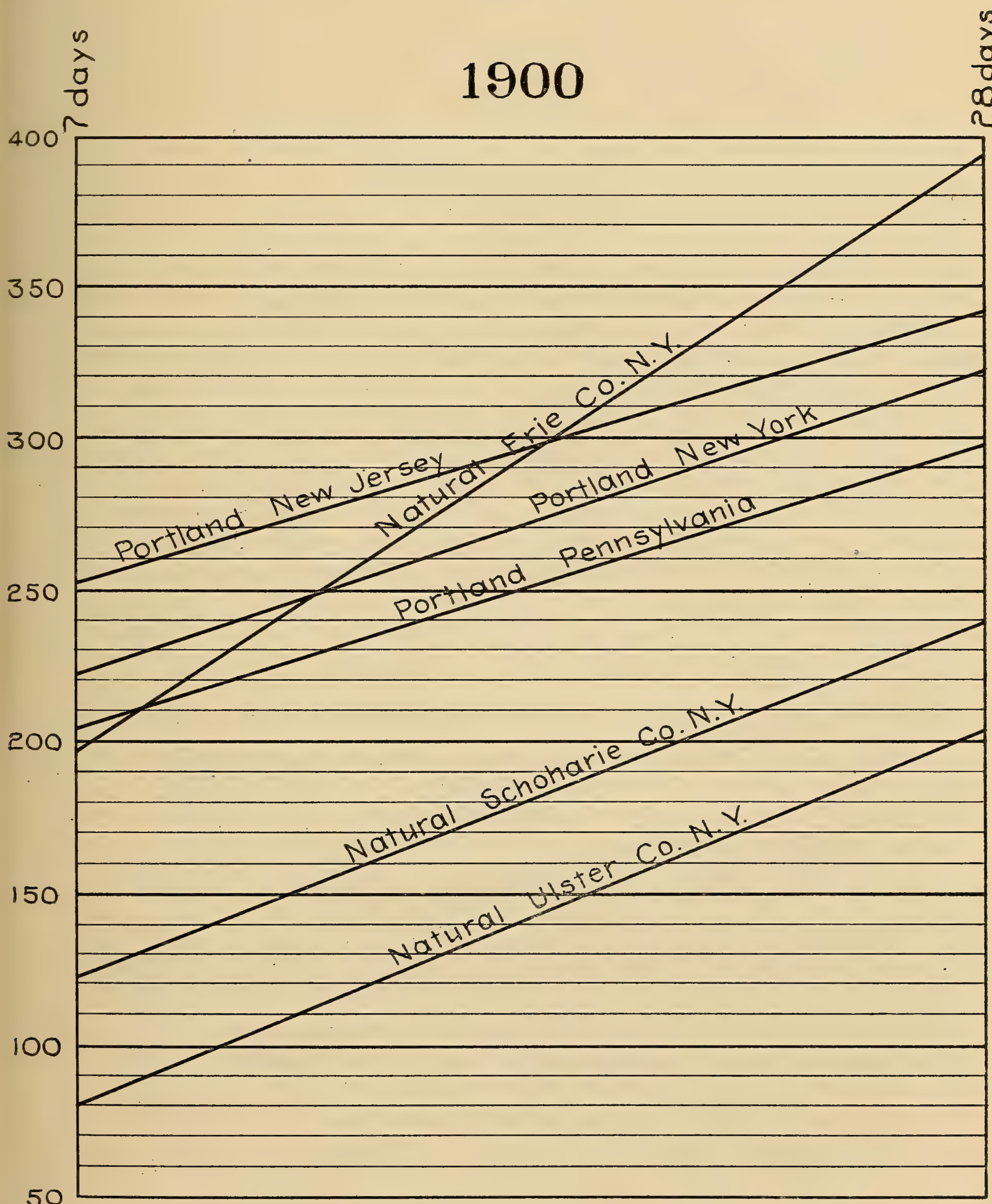
Plate 93



Tensile strength, in pounds per square inch, shown by mortar briquets
Portland briquets contain 3 sand, 1 cement.
Natural briquets contain 1 sand, 1 cement.

RESULTS OF TESTS FOR TENSILE STRENGTH

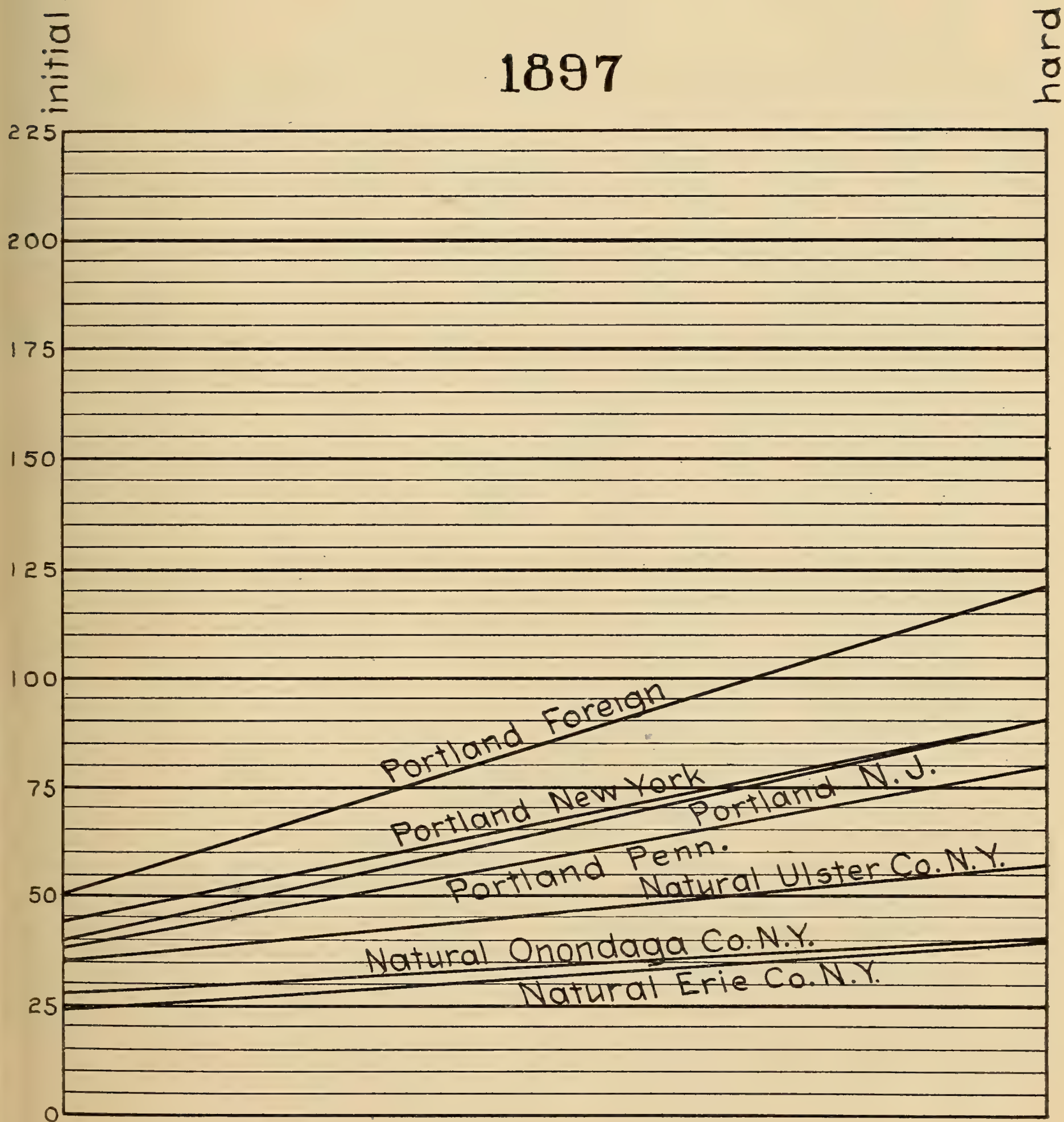
Plate 94



Tensile strength, in pounds per square inch, shown by mortar briquets
Portland briquets contain 3 sand, 1 cement.
Natural briquets contain 1 sand, 1 cement.

RESULTS OF TESTS FOR TENSILE STRENGTH

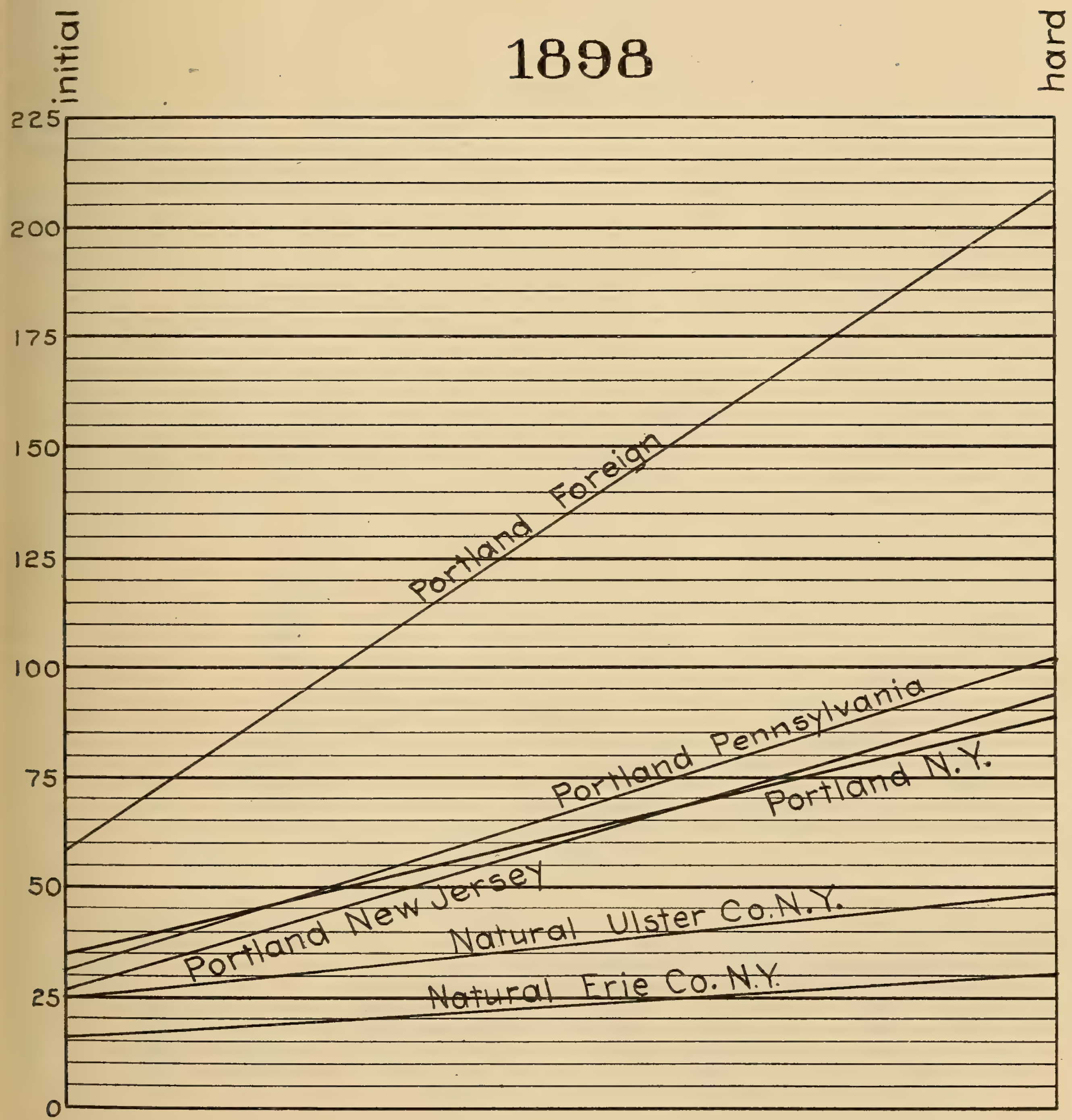
Plate 95



Time of setting shown in minutes

RESULTS OF TESTS FOR TIME OF SETTING

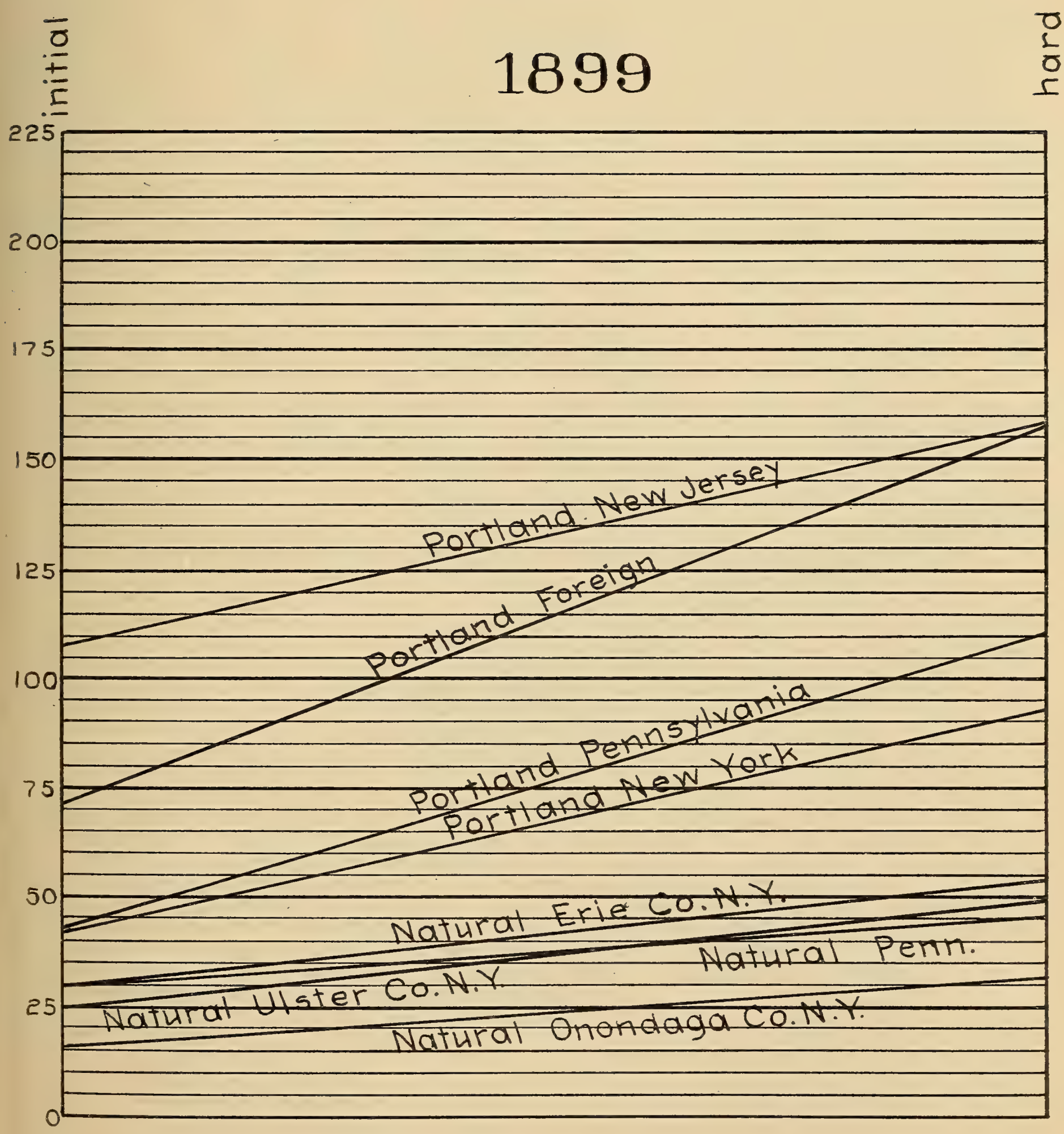
Plate 96



Time of setting shown in minutes

RESULTS OF TESTS FOR TIME OF SETTING

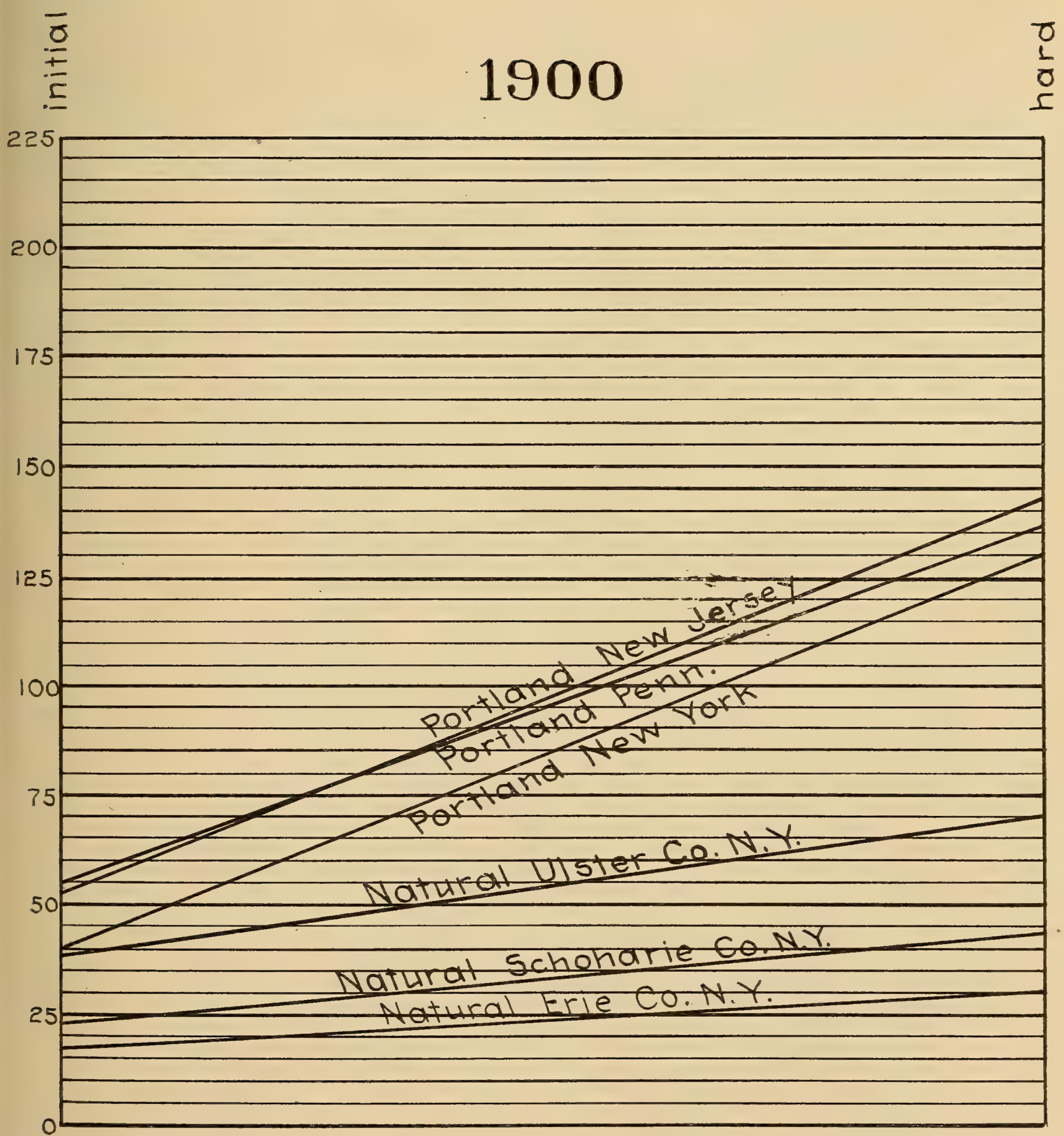
Plate 97



Time of setting shown in minutes

RESULTS OF TESTS FOR TIME OF SETTING

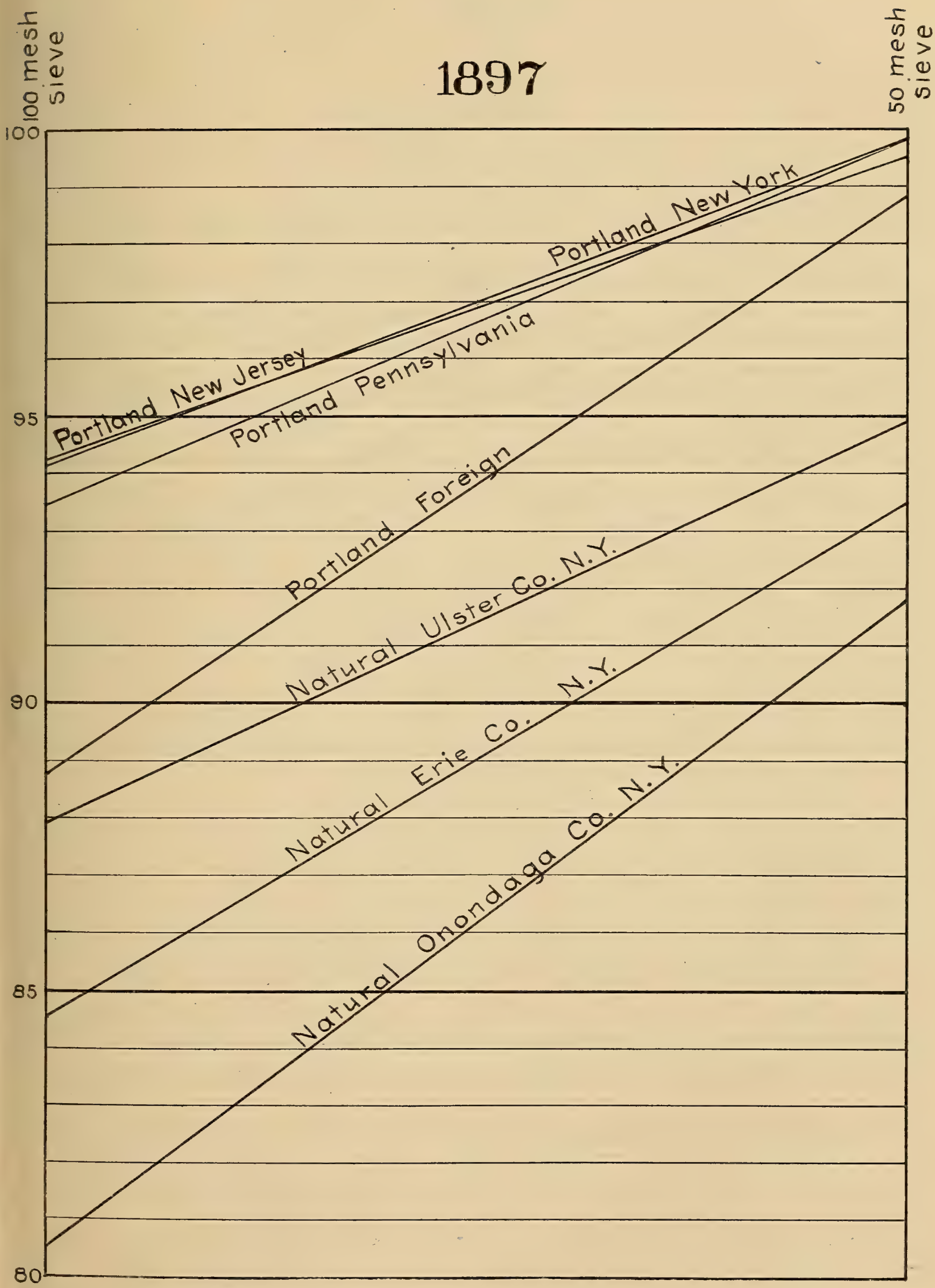
Plate 98



Time of setting shown in minutes

RESULTS OF TESTS FOR TIME OF SETTING

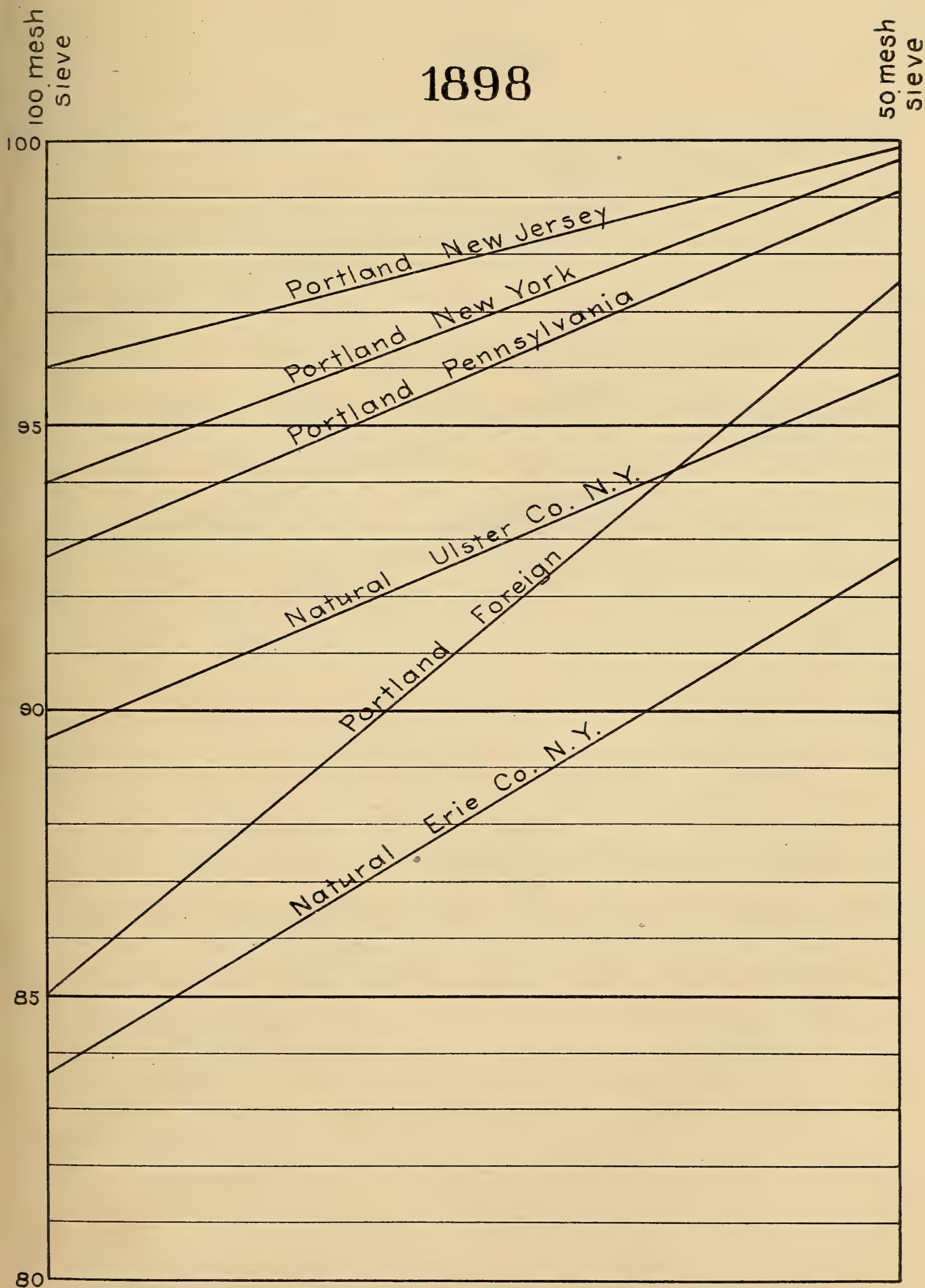
Plate 99



Fineness of cements submitted: shown in percentages passing 100 mesh and 50 mesh sieves

RESULTS OF TESTS FOR FINENESS

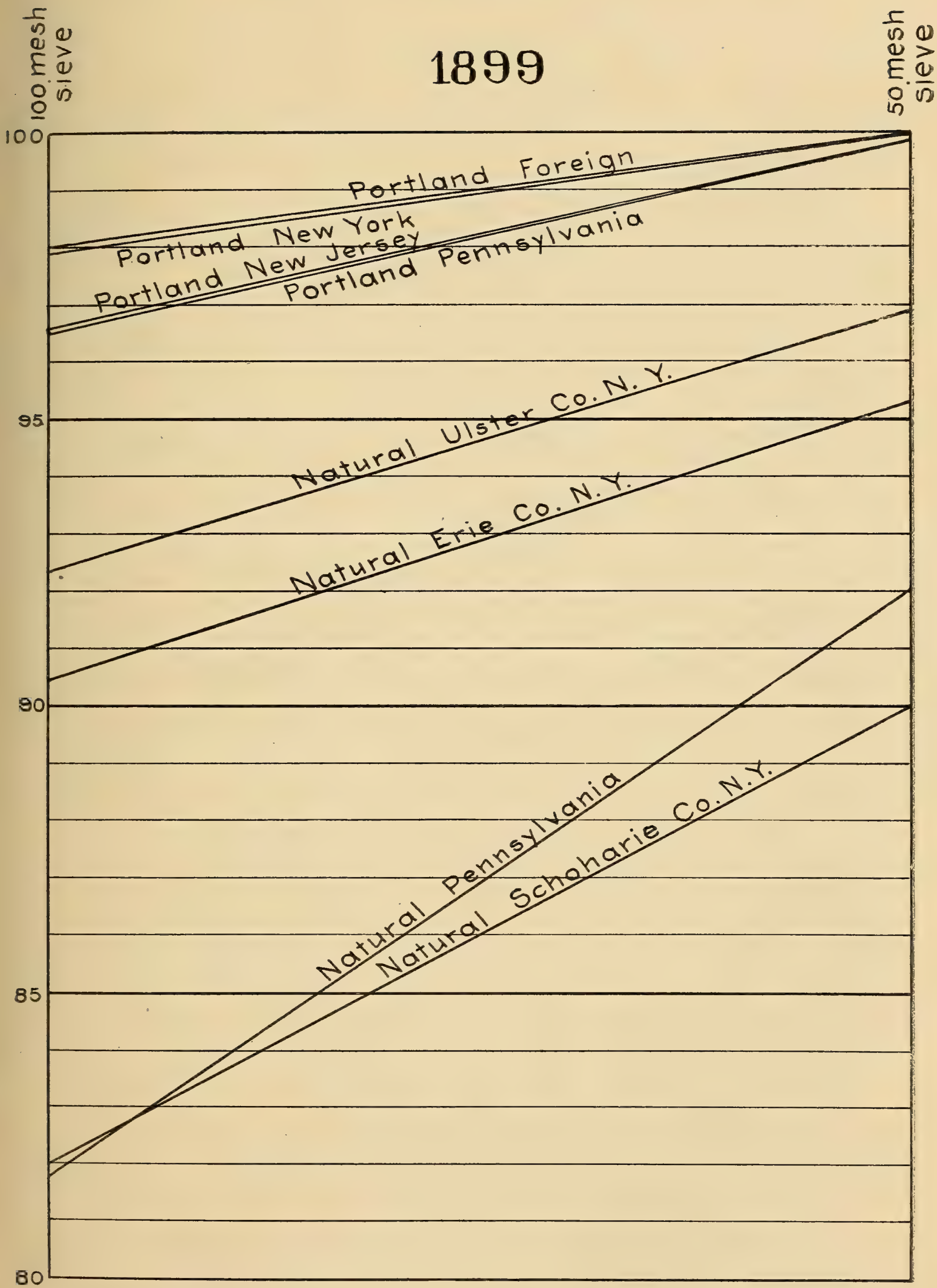
Plate 100



Fineness of cements submitted: shown in percentages passing 100 mesh and 50 mesh sieves

RESULTS OF TESTS FOR FINENESS

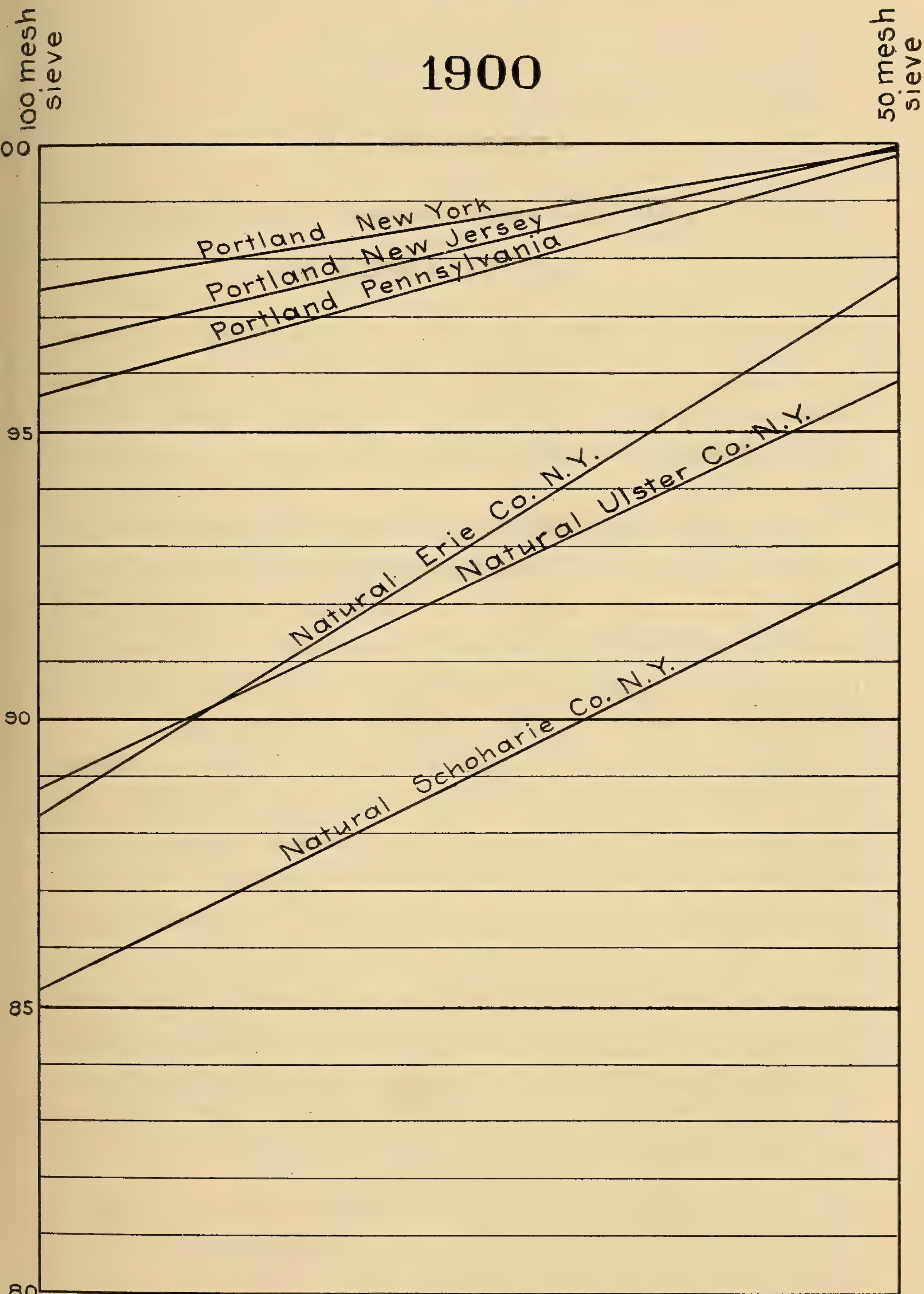
Plate 101



Fineness of cements submitted: shown in percentages passing 100 mesh and 50 mesh sieves

RESULTS OF TESTS FOR FINENESS

Plate 102



Fineness of cements submitted: shown in percentages passing 100 mesh and 50 mesh sieves

RESULTS OF TESTS FOR FINENESS

Appendix D

KEY TO THE TABLES OF LIMESTONE ANALYSES

BY EDWIN C. ECKEL C. E.

The limestone analyses which follow this section were collected by Dr Heinrich Ries. They have been carefully rearranged and revised in this office. Each analysis has been compared with its original published record, and the tables are, it is believed, entirely reliable.

At the suggestion of Dr F. J. H. Merrill the present writer has prepared a key to the tables of analyses to facilitate reference. This key is based on composition, and will be of use in determining the areas from which limestones of any given composition may be obtained. A table has been prepared in which its results are summed up, classified both by composition and by states.

For most commercial uses the components of greatest interest in a limestone are its lime carbonate, magnesium carbonate, and silica plus alumina. The limestones whose analyses are given in the following tables have, therefore, been first divided into four primary groups, the grouping being based on the percentages of lime carbonate in the rock. Each of these primary groups is then subdivided, according to the percentages of magnesium carbonate present. Finally, the secondary groups thus obtained are again divided according to the percentages of silica and alumina contained in the rocks. As shown in the summary below, 20 groups are thus formed.

KEY TO GROUPING

Calcium carbonate 95% or over.................... Group 1

Calcium carbonate 85% to 95%

Magnesium carbonate less than 5% .... Group 2

Magnesium carbonate over 5% .... Group 3

Calcium carbonate 60% to 85%

Magnesium carbonate less than 5%

Silica and alumina less than 10%	Group 4
10% to 20%	Group 5
more than 20%	Group 6

Magnesium carbonate 5% to 20%

Silica and alumina less than 10%	Group 7
10% to 20%	Group 8
more than 20%	Group 9

Magnesium carbonate more than 20%

Silica and alumina less than 10%	Group 10
10% to 20%	Group 11

Calcium carbonate less than 60%

Magnesium carbonate less than 5%

Silica and alumina less than 10%	Group 12
10% to 20%	Group 13
more than 20%	Group 14

Magnesium carbonate 10% to 20%

Silica and alumina less than 10%	Group 15
10% to 20%	Group 16
more than 20%	Group 17

Magnesium carbonate more than 20%

Silica and alumina less than 10%	Group 18
10% to 20%	Group 19
more than 20%	Group 20

If, now, limestone of a particular composition be sought, its place in the tables can be readily ascertained. The first step is to find from the "Key to grouping" above, in what group limestones of the desired composition will fall. This ascertained, the preliminary scheme *immediately* following this appendix will show in what states limestones of that group may be found, the limestones being designated by numbers corresponding to those used in the regular "Tables of limestone analyses" which follow the preliminary scheme.

KEY TO TABLES OF

STATE	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
Alabama	1, 2, 4, 8, 11, 12, 15, 16	5	......	......	10
Arkansas	38	29, 30	......	......	......
California	......	......	......	......	......
Colorado	......	......	......	......	......
Connecticut	......	......	......	......	......
Georgia	95, 99, 102	101, 104	......	105	......
Illinois	106	119	107	......	......
Indiana	134, 136, 137, 141, 142, 151–57, 164–71, 187–90	124, 129–32, 135, 138, 143, 146, 148, 149, 177	145, 158, 159, 160, 162, 172, 173, 174, 175, 176, 179–82	144, 147, 150, 192	......
Iowa	197, 198	195, 204	199	203	......
Kansas	209, 212, 218, 219, 226, 251–53	207–8, 210, 211, 213, 215, 216, 221, 223–25, 227, 230, 235, 237–40, 247, 256, 258, 259, 261, 262	206, 228, 229	241	214, 217, 236, 242, 248–50, 254, 255, 257, 260
Kentucky	264, 269, 275, 277, 278, 291, 298, 309, 354, 355	263, 274. 285, 286, 297, 299, 304–7, 318, 334, 336, 351, 353, 356, 357	279, 300, 303, 306, 311, 314, 315, 316, 337	287, 348	276, 333, 335, 349
Louisiana	359, 360	......	......	......	......
Maine	361–63	......	......	......	......
Maryland	368–70, 372, 377, 379, 380	366, 371. 373, 378	......	......	......
Massachusetts	381, 384, 386, 387	......	......	......	......
Michigan	390, 400, 401. 408, 409	396	395, 397–98, 402	......	......
Minnesota	......	411	......	......	......
Mississippi	......	......	......	......	......
Missouri	428, 430, 431, 433–40	......	429	......	......
Montana	......	446, 447	441	......	......
Nevada	......	452, 453	......	......	......

LIMESTONE ANALYSES

GROUP 6	GROUP 7	GROUP 8	GROUP 9	GROUP 10	GROUP 11	GROUP 12	GROUP 13	GROUP 14	GROUP 15	GROUP 16	GROUP 17	GROUP 18	GROUP 19	GROUP 20
6	....	....	....	....	....	....	....	....	....	9	....	3, 17	....	....
....	....	....	....	....	....	....	....	19. 20, 37	....	....	....	22, 23, 27, 31, 32, 34, 35	18, 21, 24, 25, 26, 28, 36	....
39	....	....	....	....	....	....	....	....	....	....	....	40	....	....
42	....	....	....	....	....	....	....	....	....	....	....	41	....	43
....	....	....	....	....	....	....	....	....	....	....	....	88, 90	....	....
....	....	....	....	....	....	....	....	....	....	96	....	91, 94, 98, 100, 103	93	92
....	....	....	....	....	....	....	....	....	....	....	....	108, 109, 110, 111, 112, 115	113	114 116, 117
....	120–123, 140, 178	....	....	139	133	....	....	....	....	125	161, 183, 184, 186	120, 126, 127, 128, 163, 185, 191, 193	....	133, 161, 312
....	....	....	205	194	....	202	....	....	200–1	....	....	196	....	....
....	....	222	....	....	220, 245	....	....	....	....	....	....	243 244, 246	....	....
....	265, 267, 270, 271, 290, 308, 339, 347	296, 341	348	272, 305 338, 340	....	....	310	280, 326	273, 332,	267, 313, 329	262, 261, 319–22, 327–30	282, 288, 289, 317, 322, 323, 324, 325, 344, 345, 358	268, 283, 284, 295, 331, 346	302, 320, 321, 350, 352
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	367	....	....	....	....	....	....	....	376	364	....	365, 374–75	....	....
....	....	....	....	....	....	....	....	....	388	....	....	389	....	....
....	399	....	....	....	....	....	....	....	....	....	....	403–7	....	....
....	402	418, 421,	....	413	....	....	....	....	425	....	422, 426	410, 412, 414, 415, 416, 423–24	417, 419, 420	....
....	....	427	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	432	....	....	....
....	....	....	444	....	....	....	....	445	....	....	448	442, 443	....	449
451	....	....	....	....	....	....	....	....	....	....	....	450	....	....

KEY TO TABLES OF LIME

STATE	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
New Jersey......	484, 488, 490, 502, 506-7, 526, 539, 544, 546, 551, 553, 564, 565, 592-93, 606, 610, 615, 639	471, 485-86, 491, 494, 496, 497, 500, 501, 504, 508, 510, 512, 514, 515, 517-19, 525, 533, 534, 537, 543, 545, 566-70, 601, 604, 607	487, 492, 542, 549, 552, 561, 603, 608, 611, 614	464, 479, 493, 513, 527, 571, 613	455, 465, 489, 498, 529, 535, 538, 547, 554, 555, 572-78, 580, 581, 590, 596-99, 618, 619, 622, 624, 630, 633, 635-38
New York........	643, 644, 649, 652, 658, 695, 697, 701, 703	645, 646, 650, 651, 654-57, 659, 660, 664-67, 671-73, 675-80, 696, 699	641, 685, 692, 694	640, 645, 656, 698, 700	642
Ohio	715, 736, 757, 772, 777	719, 720, 732, 755	721, 728, 730, 733, 735 738, 739, 750, 753	....	718, 724, 749, 758
Pennsylvania	789, 796-98, 803, 806, 809, 812, 814-16, 849, 851, 854-56, 858, 862, 863, 869	787, 790-93, 821, 822, 828, 830-33, 836, 839, 844, 850, 852, 853, 857, 872, 883, 884, 888, 898, 899	788, 801, 804, 807, 868, 877, 879, 881, 904	871	811, 818, 819, 825, 840, 843, 846, 847, 893, 902
Rhode Island	....	....	......	....	....
South Dakota....	....	....	......	....	....
Tennessee........	909	....	......	....	....
Texas	910	....	......	....	....
Vermont.........	914, 920-26	....	......	....	....
Virginia.........	....	937	929	....	....
West Virginia....	944, 946, 947, 950, 956, 963, 968	943, 964-67, 971, 973	940-42, 945, 964, 969, 972, 974	955	961, 975
Wisconsin	....	....	......	....	....

STONE ANALYSES (*concluded*)

GROUP 6	GROUP 7	GROUP 8	GROUP 9	GROUP 10	GROUP 11	GROUP 12	GROUP 13	GROUP 14	GROUP 15	GROUP 16	GROUP 17	GROUP 18	GROUP 19	GROUP 20
478, 579, 582, 583, 586–88, 600, 617, 621, 623, 625, 626, 629, 631, 634	530, 531	472, 511, 516, 576, 584, 585	547	509, 525, 531	....	520, 521	....	548, 589, 605, 620, 627, 628, 632	454, 474, 523, 528, 540, 541, 550	461, 473, 476	594	456–60. 462, 466–70, 475, 477, 480–83, 499, 505, 522, 524, 536, 550, 556–58, 560, 563, 591, 595, 602, 609, 612, 616	503 559	463, 495, 533. 562
....	668, 674, 688, 693, 704, 707	....	....	670	682,	....	....	....	....	691	....	647, 648, 661–63, 669, 690, 705–10	653, 683, 684, 686, 687, 689	....
....	741, 754, 760, 776, 785, 786	727. 751	....	752, 769	....	....	....	....	....	....	725, 726	711–14, 716, 717, 728, 729, 731, 735, 737, 740, 742–48, 756, 759, 761–68 770–73, 775, 778, 779–84.	734, 748	722
878, 880	805, 810, 826, 859, 871, 873 882, 890	837, 845, 876, 886, 891, 894, 901	....	860	....	....	....	823, 824, 829, 870, 892, 900	....	842, 875, 887, 889	838, 841, 875, 892	778–84, 794, 795, 799, 800, 802. 808, 817, 848, 861, 865–67, 903	885, 896, 897	813, 827, 895
....	905	....	....	....	....	....	....	....	....	....	....	....	....	....
....	906	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
932	928, 935, 938	....	....	934	....	....	....	....	....	....	....	927, 930, 931, 933, 936	....	....
....	948, 960, 962	954, 957, 958, 970	....	....	....	....	....	....	....	....	951, 952, 959	949	....	953
....	....	....	....	....	....	....	....	....	....	....	....	976–79, 983–88	980–82	....

ANALYSES OF LIMESTONES

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Alabama									
1	Blount..........	Blount Springs	.5	.4		99.1	....	......	....	......
2	Calhoun........	Anniston	.74	.36		98.76	trace	......	....	......
3	"	Morrisville	3.24	.17	.17	*a*29.58	*b*20.84	45.54	....	......
4	Colbert.........	Sheffield	.5	....	1.45	*a*54.2	*b*1.23	42.61	....	......
5	Conecuh........	Evergreen	2.75	1.09	1.64	*a*52.36	*b*.11	41.44	....	......
6	Dallas...........	Cahaba	19.64	4.72	4.63	66.37	.79	......	....	......
7	DeKalb.........	Fort Payne........L	1.69	....	....	*a*96.12	*b*.11	......	....	......
8	Franklin	Russellville	.9	.7	... ...	97	1.4	......	....	......
9	Lowndes	Benton................	19.74	7.74	3.93	*a*30.77	*b*2.45	26.39	....	......
10	Marengo........	Demopolis	12.13	4.17	3.28	75.07	*b*.92	......	....	......
11	Shelby	Longview	......	.13		99.11	.75	......	.39	......
12	"	"	......	trace		99.16	.75	......	.15	......
13	"	" L	.....	.26		*a*98.44	*b*.98	......	.18	......
14	"	" L	......	.21		*a*97.3	......	......	.37	......
15	"	Shelby	.23	.21	trace	99.13	.12	......	....	......
16	"	Siluria	.10	.63		98.91	.58	......	....	......
17	Talledaga	Stanley	......	1.47		55.95	40.9	......	1.34	......
	Arkansas									
18	Carroll	Beaver	8.66	4.77		48.48	33.58	......	....	......
19	Clark	Okolona	......	7.99	7.42	22.04	2	.....	& SiO_2 53.07	......
20	"	Boseman place......	......	6.735	4.65	35.95	*b*1.306	......	& SiO_2 44.04	......
21	"	Leatherwood switch	8.65	4.72		47.91	39.23	......	....	......
22	"	"	......	....	....	49.53	40	......	....	......
23	"	Waldons.............	. ...	.... .	....	49.47	40.85	......	....	......
24	Desha	White River.........	13.52	.89		48.23	38.36	......	....	......
25	Eureka Springs	Eureka Springs.....	14.71	.... .	....	47.43	35.76	.....	....	......
26	"	3 m. s. e. of Yellville	12.07	......	..... .	48.53	37.91	......	....	......
27	Lawrence	Hoppe mine.........	....	....	....	53.998	35.059	......	6.701	......
28	"	Koch mine	......	& Mn 1.482		50.075	32.487	4.985	10.935	......
29	Little River.....	Rocky Comfort.....	...	1.25		88.48	*b*tr.	......	& SiO_2 9.77	. ....
30	"	White Cliffs.........	......	1.41		94.18	1.37	......	& SiO_2 3.49	......
31	Marion	Wood's mine........	......	& Mn 3.023		50.041	42.817	......	3.191	......
32	Newton	Mt Hersey...........	8.01	1.21		56.58	34.69	.....	....	......
33	"	20 n. 18 w. s. 35	......	....	....	......	36.75	.....	....	......
34	"	19 n. 17 w. s. 17	.....	......	....	49.89	37.21	......	....	......
35	"	19 n. 17 w. s. 7	......	....	..... .	32.25	24.02	......	....	.....
36	"	19 n. 18 w. s. 11.......	12.76	....	....	48.22	37.89	.. ...	....	......

*a*CaO *b*MgO

OF THE UNITED STATES

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
1	....	U. S. geol. sur. 20th rep't, pt 6, p. 354; Dr W. B. Philips, anal.	A. P. Birch quarry
2	....	U. S. geol. sur. 20th rep't, pt 6, p. 354; W. Mackemson, anal.	Anniston lime works co.
3	FeO .06	U. S. geol. sur. Bul. 168, p. 258	Knox dolomite
4	....	" 20th rep't, pt 6, p. 354...............	T. L Fossick
5	SO_3 .018 Alkalis .14	Ala. ind. and sci. soc. 5:44-51.............	
6	Alkalis .04	" "	
7	SO_3 trace P_2O_5 .01	U. S. geol. sur. 20th rep't, pt 6, p. 354-55; A. D. Brainerd, anal.	Standard lime co.
8	....	U. S. geol. sur. 20th rep't, pt 6, p. 354-55; J. C. Foster, anal.	Franklin quarry co.
9	SO_3 .85 Alkalis 2.88	Ala. ind. and sci. soc. 5:44-51..	
10	Alkalis .09 $Ca_3P_2O_8$ .4	" "	
11	....	U. S. geol. sur. 20th rep't, pt 6, p. 354-55; E. A. Smith, anal.	Longview lime works, no. 1
12	....	U. S. geol. sur. 20th rep't, pt 6, p. 354-55; E. A. Smith, anal.	" no. 2
13	CO_2 .32	U. S. geol. sur. 20th rep't, pt 6, p. 354-55; W. Stubbs, anal.	"
14	....	U. S. geol. sur. 20th rep't, pt 6, p. 354-55............	"
15	P_2O_5 trace	" "	Shelby iron co.
16	....	" "	T. L. Fossick
17	....	U. S. geol. sur. 20th rep't, pt 6, p. 354-55; A. Noble, anal.	J. T. Landt
18	$CaSO_4$ .42	U. S. geol. sur. 20th rep't, pt 6, p. 354-55; Navy dep't, Wash. anal.	Mark Liles
19	Loss on ign. 4.74	Ark. geol. sur. 1888, 2:237	Sandy lime marl
20	SO_3 1.7 P_2O_5 .234	" "	Rich lime marl
21	....	" 1890, 4:117.........................	
22	....	" "	
23	....	" "	
24	....	" "	18 n. 13 w. section 36
25	....	" "	
26	....	" "	
27	$FeCO_3$ 2.25 $ZnCO_3$ 1.98 Alkalis .106	" "	
28	Alkalis .136	" "	
29	....	" 1888, 2:237.........................	Chalk
30	Loss on ign. .55	" "	Chalk
31	$ZnCO_3$ 1.95 Alkalis .435	" 1890, 4:117.........................	
32	....	" "	
33	....	" "	
34	....	" "	
35	....	" "	
36	....	" "	

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Arkansas (*c'd*)									
37	Sevier	Brownstown	......	4.26	4.86	46.73	1.51	......	41.72	......
38	Washington....	Johnson	......		.17	99.34	....	......	.39	.1
	California									
39	Contra Costa ..	Mt Diablo............	21.19	.39	1.52	*a*35.61	*b*1.39	26.84	....	.76
40	Inyo............	Near Keeler.........	......	....	.017	*a*31.042	*b*21.791	47.353	....	......
	Colorado									
41	Arapahoe	Denver	......	.54	.11	*a*27.49	*b*18.03	41.4	12.01	.61
42	Garfield	Glenwood Springs...	......	......	.97	*a*40.64	*b*.73	32.73	21.45	......
43	"	" ..	.....	....	.18	*a*15.87	*b*10.6	4.13	47.74	......
44	"	" ..	......	....	.42	*a*46.65	*b*2.64	39.55	6.47	......
45	"	" ..	......	....	....	*a*47.4	*b*4.49	42.15	3.71	......
46	"	" ..	......	....	.26	*a*39.56	*b*8.56	40.52	9.44	.....
47	"	" ..	......	....	.74	*a*26.5	*b*14.86	37.18	17.82	......
48	"	" ..	......	......	.03	*a*32.14	*b*18.72	45.85	1.96	.....
49	"	" ..	......	....	trace	*a*55.17	*b*.21	43.58	.22	......
50	"	" ..	......	....	.14	*a*53.79	*b*.46	42.76	2.27	......
51	"	" ..	......	....	.09	*a*55.49	*b*.24	43.87	.23	......
52	"	" ..	......	....	....	*a*55.81	*b* trace	43.85	.06	......
53	"	" ..	.....	......	.1	*a*55.45	*b* 4	43 84	.22	......
54	"	" ..	......	....	.03	*a*55.68	*b* trace	43.75	.11	......
55	Jefferson.......	Morrison	......	.53	.38	*a*48 73	*b*2.95	41.71	5.32	.11
56	Lake	Leadville	.21	.27	.21	*a*30.79	*b*21.14	46.84	....	.22
57	"	"	.7	.17	.11	*a*30.43	*b*20.78	46.93	....	.04
58	"	"	.27	.04	.22	*a*29.97	*b*21.52	47.39	....	.07
59	"	"	7.76	.11	.1	*a*27.26	*b*20.05	43.79	....	.05
60	"	"	11.84	1.66	1.51	*a*26.6	*b*17.41	40.01	....	.48
61	Ouray..........	Ouray...............	......	trace	....	97.3	trace	....	....	......
62	Park	Fairplay.............	......	....	....	*a*53.64	*b*.73	42.93	2.37	.51
63	"	Buckskin gulch.....	17.64	.99	.62	*a*32.23	*b*19.01	25.33	....	3.72
64	"	Mt Silverheels......	......	....	....	*a*55.5	*b*.17	43.82	.51	......

*a*CaO *b*MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS		REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
37	....		Ark. geol. sur. 1888, 2:237..........................	Sandy lime marl
38	....		U. S. geol. sur. 20th rep't, pt 6, p. 358; G. L. Teller, anal.	Crescent white lime co.
39	MnO	3.61	U. S. geol. sur. Bul. 148, p. 275; W. H. Melville, anal.	
40	....		U. S. census 1890 min. ind. p. 607..................	
41	MnO	.20	U. S. geol. sur. Bul. 168, p. 270; L. G. Eakins, anal..	Niobrara limestone
42	FeO	.23	" 148, p. 273; G. Steiger, anal....	
43	FeO	.71	" " "	
44	FeO	.35	" " "	
45	FeO	.55	" " "	
46	FeO	.32	" " "	
47	FeO	.57	" " "	
48	FeO	.35	" " "	
49	....		" " "	
50	....		" " "	
51	....		" " "	
52	....		" " "	
53	FeO	.1	" " "	
54	FeO	.07	" " "	
55	P_2O_5 MnO	.03 .49	" 168, p. 270; L. G. Eakins, anal..	Upper Wyoming limestone
56	FeO Cl Alkalis	.24 .1 .09	" " p. 271, W. F. Hillebrand, anal.	Silver Wave mine
57	FeO MnO Alkalis Cl P_2O_5	.38 .05 .14 .14 .12	U. S. geol. sur. Bul. 168, p. 271, A. Guyard, anal...	Dugan quarry
58	FeO MnO Alkalis P_2O_5 Org.	.13 .2 .03 .03 .02	" " " ...	Glass-Pendery mine
59	FeO MnO Alkalis P_2O_5 Cl FeS_2 Org.	.57 .06 .06 .07 .06 trace .07	" " " ...	Montgomery quarry
60	Alkalis FeO	.05 .83	" " p. 271, W. F. Hillebrand, anal.	Carbonate Hill quarry
61	....		Am. inst. min. eng. Trans. 16:586	
62	FeO	.19	U. S. geol. sur. Bul. 148, p. 272; W. F. Hillebrand, anal.	
63	FeO MnO Alkalis P_2O_5 Cl	.18 trace .07 .05 .08	U. S. geol. sur. Bul. 148, p. 272; W. F. Hillebrand, anal.	Serpentinous limestone
64	....		U. S. geol. sur. Bul. 148, p. 272; W. F. Hillebrand, anal.	

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Colorado (c'd)									
65	Park	Mt Silverheels	......	......	......	a30.19	b20.47	46.52	1.98	......
66	Pitkin	......	......	......	.22	a30.66	b20.94	47.13	.16	......
67	"	......	......	......	1.63	a31.19	b19.69	46.16	.8	......
68	"	......	......	......	2.1	a33.74	b16.76	44.94	1.02	......
69	"	......	......	......	1.88	a35.98	b8.25	37.35	13.63	......
70	"	......	......	......	3.34	a31.61	b18.06	44.7	1.42	......
71	"	......	......	......	.36	a37.28	b.54	29.88	31.12	......
72	"	......	......	......	.88	a38.85	b9.97	41.47	7.78	......
73	"	Aspen	......	......	.88	a31.16	b20.64	47.19	.52	......
74	"	"	......	......	trace	a55.81	b.16	44.03	.33	......
75	"	"	......	......	1.31	a30.46	b20.9	46.92	.84	......
76	Pueblo	Pueblo	76.8	1.71	1.23	a49.06	b.56	......	......	......
77	Summit	Copper mountain	......	......	......	a54.23	b.21	42.97	2.69	......
78	"	Pittston tunnel	......	......	......	a55.24	b.24	43.81	.62	......
79	"	Pearl hill	......	......	......	a28.01	b18.33	42.63	10.09	......
80	"	Summit quarry	......	......	......	a53.6	b1.23	43.65	1.75	......
81	"	......	......	......	......	a55.17	b.28	43.76	1.37	......
82	"	Pittston tunnel	......	......	......	a50.83	b.7	40.9	7.91	......
83	"	Summit King shaft	......	......	......	a28.05	b18.15	43.88	6.75	......
84	"	North of Sugar Loaf	......	......	......	a52.97	b.4	42.12	4.42	......
85	"	Searls gulch	......	......	......	a55.58	b.37	44.17	.36	......
86	"	Elk mountain	......	......	......	a55.47	b.22	43.86	.82	......
87	"	Jacque mountain	......	......	......	a54.62	b.25	43.28	2.04	......
	Connecticut									
88	Litchfield	Canaan	.08	.25		54.4	45.12	......	......	......
89	"	" L	.42	......	......	a56.57	b42.56	......	......	......
90	"	East Canaan	......	.2		a31.31	b21.03	46.98	.48	......
	Georgia									
91	Bartow	Cave spring	3.5	......	1.5	53.44	41.15	......	......	......
92	"	Cement	22.1	5.45	1.8	43.5	26	......	......	......
93	"	"	10	6.1	2	55	26.1	......	......	......
94	"	Egyptian quarry	6.47	2.68	2.1	52.05	36.32	......	......	......
95	Dade	Rising Fawn	......	.1		96.13	2.05	.95	......	...
96	Floyd	Rome	10.95	3.5	2.05	43.8	8.79	....	......	......
97	Jefferson	Bartow L	7.252	1.236		a34.07	b55.736	......	......	1.622
98	"	"	1.94	1.5		56.02	38.43	......	......	
99	Pickens	Dykes creek	.62	.25	......	97.32	1.6	......	......	.....

aCaCO bMgO

THE UNITED STATES (*continued*)

No.	Miscellaneous	Reference and analyst	Owner location and remarks
65	FeO, MnO .46	U. S. geol. sur. Bul. 148, p. 272; W. F. Hillebrand, anal.	
66	FeO .09	U. S. geol. sur. Bul. 148, p. 272; G. Steiger, anal....	
67	FeO .23	" " "	
68	FeO .06	" " "	
69	FeO .61	" " "	
70	FeO .42	" " "	
71	FeO .19	" " "	
72	FeO .22	" " "	
73	....	" p. 273, L. G. Eakins, anal..	Blue limestone
74	....	" " " ..	
75	....	" " " ..	
76	P_2O_5 .033	Am. inst. min. eng. Trans. 23:580..................	
77	FeO & MnO .21	U. S. geol. sur. Bul. 168, p. 274; W. F. Hillebrand, anal	
78	FeO & MnO .25	" "	
79	FeO & MnO 1.19	" "	Middle Carboniferous
80	FeO & MnO .32	" "	
81	FeO & MnO .20	" "	
82	FeO & MnO .32	" "	
83	FeO & MnO 3.08	" "	
84	FeO & MnO .1	" "	
85	FeO & MnO .17	" "	
86	FeO & MnO .07	" "	
87	FeO & MnO .15	" "	Triassic
88	....	U. S. geol. sur. 20th rep't, pt 6, p. 370; J. S. Adam, anal.	Canaan lime co.
89	....	U. S. geol. sur. 20th rep't, pt 6, p. 370; J. S. Adam, anal.	" "
90	....	U. S. geol. sur. 20th rep't, pt 6, p. 370; J. S. Adam, anal.	Canfield Bros. quarry
91	....	Ga. geol. sur. 1893, p. 263; J. M. McCandless, anal.	
92	Org. .15	" p. 264; W. J. Land, anal........	
93	....	" " "	
94	....	" p. 266; J. M. McCandless, anal.	
95	....	" " "	
96	....	" p. 263 "	
97	....	U. S. geol. sur. 20th rep't, pt 6, p. 375; N. Pratt, anal.	A. C. Ladd lime works
98	....	U. S. geol. sur. 20th rep't, pt 6, p. 376; N. Pratt, anal.	" "
99	FeO .26	Min. res. U. S. 1890, p. 387; J. C. Jackson, anal.....	

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Georgia (*c'd*)									
100	Pickens	Dykes creek	6.25	1.7		52.64	39.44	......	.21	......
101	Polk	Cedartown	......	....	2.23	94.37	2.1	......	....	......
102	"	Dewitte lime quarry	......	.4		95.2	2.171	......	2.3	......
103	"	Lookout creek......	......	9.5	....	55.47	25.33	8.16	....	......
104	"	South of Trenton ...	......	1.8		91.4	3.5	2.82	....	......
105	"	Sand mountain	......	3.2		80.6	2.45	1.27	....	......
	Illinois									
106	Adams	Marblehead	.47	2.18		95.62	.82	......	....	&org. .91
107	"	Quincy	......	.27		92.77	6.75	......	.37	......
108	Cook	Chicago	......	.55		52.75	44.28	......	.6	......
109	"	"	......	1.48		52.76	45.04	......	.21	&loss .51
110	"	"	......	1.04		53.7	42.34	......	1.28	......
111	"	"	......	1.78		52.07	42.18	......	4	......
112	"	"	......	.58		54.99	44.04	......	.87	......
113	"	"	.34	2.04		23.39	19.4	......	54.15	......
114	"	"	......	....		52.08	37.54	......	....	......
115	Kankakee	Kankakee...........	3	2.5		*a*30.45	*b*20.5	......	....	......
116	"	"	26.08	6.57		46.9	14.19	......	....	......
117	La Salle........	La Salle..............	21.12	1.12		42.25	31.98	......	....	1.07
118	Madison	Alton..............L.	1.01	1.1	....	*a*97.72	......	......	....	......
119	Will	Joliet	3.70	2.5	......	92.14	1.75	......	....	......
	Indiana									
120	Adams	....	.53	.46	.01	54	45	......	....	......
121	Blackford	Montpelier	2.75	4.7		*a*42.92	*b*3.88	41.2	....	.95
122	"	"	2.68	5.25		*a*42.55	*b*4.4	39.1	....	1.25
123	"	"	2.43	5.17		*a*43.01	*b*4.18	41.55	....	1.—
124	Cass	Kenneth.............	1.33	2.07		93.48	*b*1.16	......	....	1.57
125	Clarke	Silver creek.........	18.33	4.98	1.67	54.31	16.9	......	....	......
126	"	"	9.69	2.77	1.95	51.95	32.97	......	....	......
127	"	"	9.8	2.03	1.4	52.5	35.09	......	....	......
128	Delaware........	Muncie	......	3.72		51.96	38.11	....	3.3	......
129	Decatur	Greensburg	......	.55		94.6	.36	......	.87	......
130	Elkhart	Mud lake	......	.41	.23	82.89	2 04	.....	7.94	......
131	"	Cooley lake	.....	.52	.36	88.21	4.78	.....	1.42	......
132	Fulton	Manitou lake	......	.19	.3	87.65	2.6	.....	6.39	.....
133	Franklin	Laurel	21.51	11.01		43.67	20.6	......	....	1.39
134	Harrison	Mauckport..........	......	.14	.18	98.09	....	......	.31	.12

a CaO *b* MgO

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS		REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
100	....		Ga. geol. sur. 1893, p. 265; J. M. McCandless, anal.	
101	Undet.	1.3	" p. 68; W. J. Land, anal.........	
102	....		" " "	
103	....		" " J. M. McCandless, anal.	
104	....		" p. 271; "	
105	....		" " "	
106	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; N. G. Bartlett, anal.	Marblehead lime co.
107	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; C. G. Hopkins, anal.	F. W. Menke stone and lime co.
108	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	Stearns stone and lime co.
109	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; J. B. Britson, anal.	Chicago Union lime works co.
110	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	Artesian stone and lime co.
111	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	"
112	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	Union lime co.
113	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	Blue Island quarry
114	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	Stony Island avenue quarry
115	P_2O_5	.006	U. S. geol. sur. 20th rep't, pt 6, p. 378; C. S. Robinson, anal.	Kankakee stone and lime co.
116	....		....	
117	....		Min. ind. 1:49....................................	
118	FeO	.2	U. S. geol. sur. 20th rep't, pt 6, p. 378; S. E. Swartz, anal.	Armstrong quarry
119	....		Min. res. 1886, p. 542..............................	
120	....		" 1890, p. 392............................	
121	SO_3 loss	.79 2.81	U. S. geol. sur. 20th rep't, pt 6, p. 382; S. S. Gorby, anal.	Baltes land co.
122	SO_3 loss	1 09 3.68	U. S. geol. sur. 20th rep't, pt 6, p. 382; S. S. Gorby, anal.	
123	SO_3 loss	.88 1.78	U. S. geol. sur. 20th rep't, pt 6, p. 382; S. S. Gorby, anal.	
124	loss	.39	U. S. geol. sur. 20th rep't, pt 6, p. 382; S. S. Gorby, anal.	Casparis stone co.
125	....		Ind. geol. sur. 1900, p. 366; W. A. Noyes, anal.....	"Ohio Valley" quarry
126	....		" " "	"Black Diamond" quarry
127	....		" " "	"Belknaps" Falls City quarry
128	....		U. S. geol. sur. Bul. 148, p. 263; C. Catlett, anal ..	Trenton limestone
129	....		" " " ..	"
130	Org.—	3.67	Ind. geol. sur. 1900, p. 321; Osborn eng. co., anal.	
131	Org.—	2.58	" " "	
132	Org.—	2.88	" " W. A. Noyes, anal....	
133	....		U. S. geol. sur. 20th rep't, pt 6, p. 382; W. A. Noyes, anal.	J. A. Derbyshire
134	Alkalis	.40	U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Mauckport quarry

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Indiana (*c'd*)									
135	Harrison	Mauckport	.15		.64	93.8	4.01		.15	1.09
136	Howard	Kokomo	.24	.43		98.66				
137	"	"	1.62	.6	.16	97.05				
138	"				.001	93.1			1.62	
139	"				.008	66.92	24.56		5.56	
140	Huntington	Huntington	2.75	4.7		*a*42.92	*b*4.41	41.2		.95
141	Jefferson	Big creek			.64	95.8	4.01		.15	1.09
142	"	"			.71	95.07	4.22		.5	1.19
143	Jennings	Vernon		.6		85.56	trace		8	
144	Kosciusko	Syracuse lake	1.74	.9	.28	*a*49.84	*b*1.75			
145	"	"		.9	.31	88.49	2.71		1.78	
146	"	Dewart lake		.37	.16	92.35	3.54		2	
147	"	"		.18	.3	84.24	2.85		4.52	
148	"	Tippecanoe lake		.06	.26	90.67	2.42		2.48	
149	"	"			.29	91.02	2.28		2.92	
150	"	Little Eagle lake		.15	.35	84.75	2.84			
151	Lawrence	Bedford	1.69		.49	97.26	*b*.37			.19
152	"	"	.89	.38	.25	*a*54.48	*b*.36	43.4		
153	"	"	.87	.34	.13	*a*54.68	*b*.32	43.44		
154	"	"	.64	.15		98.27	.84			
155	"	"	63		.38	*a*54.19	*b*.39	44.01		
156	"	"	1.69		.49	*a*54.18	*b*.37	43.08		
157	"	"		1.27	.13	97.48	*b*.61			.15
158	Lagrange	Turkey lake		.61	.25	91.14	2.75		.85	
159	Marshall	Maxinkuckee lake		.12	.33	85.02	3.85		5.67	
160	"	"		.05	.33	85.38	3.5		6.4	
161	"	"	53.2	26.76	4.24	12.66	3.03			
162	"	Houghton and Moore lake		.04	.2	89.22	2.73		2.02	
163	Miami	Peru	4.05	1.25	1.2	52.9	38.94			2.63
164	Monroe	Bloomington		.06	.23	95.62	.89		1.74	.59
165	"	"		.09	.09	95.55	.93		1.6	.42
166	"	"			1	95.54	.4		.65	.25
167	"	Stinesville			3	95	.22		.9	.05
168	"	Clear creek	.84	.13		97.39	.78			
169	Owen	4 m. e. of Spencer			.91	96.79	.23		.7	.41
170	Owen	Romona	1.26	.18		*a*54.82	*b*.31	43.49		

a CaO

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS		REFERENCE AED ANALYST	OWNER LOCATION AND REMARKS
135	....		U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Big Creek quarry
136	MgO	trace	U. S. geol. sur. 20th rep't, pt 6, p. 382; Grasseli chem. co., anal.	Defenbaugh & Smith
137	MgO	.36	U. S. geol. sur. 20th rep't, pt 6, p. 382; Grasseli chem. co., anal.	"
138	....		Min. res. U S. 1890, p. 392........................	
139	....		" "	
140	SO_3 Undet.	1.25 1.82	U. S. geol. sur. 20th rep't, pt 6, p. 382; G. M. Levette, anal.	Huntington white lime co.
141	....		Ind. geol. sur. 1900, p. 326; L. H. Streaker, anal...	Indiana steam stone works
142	....		" " " ...	"
143	....		U. S. geol. sur. Bul. 148, p. 263; C. Catlett, anal...	
144	SO_3 loss	1.12 46.01	Ind. geol. sur. 1900, p. 29; S. B. Newberry. anal..	Syracuse Portland cement co.
145	$CaSO_4$ Org.	1.58 4.23	" 321; " ..	
146	Org.	2.12	" " A. W. Burwell, anal..	
147	Org.	5.02	" " W. A. Noyes, anal....	
148	Org.	2.87	" " "	
149	....		" " "	
150	....		" " "	
151	....		U. S. geol. sur. 20th rep't, pt 6, p. 381; F. W. Clarke, anal.	Bedford quarries co.
152	....		U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Bedford Portland cement co.
153	....		U. S. geol sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	"
154	....		U S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Clarke, anal.	Bedford Indiana stone co.
155	P_2O_5	trace	U. S. geol. sur. Bul. 148, p. 263; F. W. Clarke, anal.	Hoosier stone co.
156	P_2O_5	trace	U. S. geol. sur. Bul. 148, p. 263; F. W. Clarke, anal.	" *see* no. 151
157	....		Ind. geol. sur. 1900, p. 328; A. W. Smith, anal	Bedford Portland cement co.
158	....		" 321; W. R. Oglesby, anal..	
159	$CaSO_4$ Org.	.17 3.21	" " W. A. Noyes, anal....	
160	$CaSO_4$ Org.	.17 3.15	" " " ...	
161	....		" 1885, p. 42.........................	
162	Org.	4.15	Ind. geol. sur. 1900, p. 321; W. A. Noyes, anal	
163	....		U. S. geol. sur. 20th rep't, pt 6, p. 382; J. N. Hurtz, anal.	Peru stone and lime co.
164	....		Ind. geol. sur. 1900, p. 326.........................	Dunn & Dunn quarry
165	....		" "	"
166	Alkalis	.55	" "	Dunn & co.
167	Alkalis	.83	" "	Monroe marble co.
168	Alkalis	.1	U. S. geol. sur. 20th rep't, pt 6, p. 381	Acme Bedford stone co.
169	Alkalis	.32	Ind. geol. sur. 1900, p. 326	Simpson & Archer quarry
170	....		U. S. geol. sur. 20th rep't, pt 6, p. 382; W. A. Noyes, anal.	Romona oolitic stone co.

*b*MgO

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Indiana (*c'd*)									
171	Owen	Romona	1.26	.18		97.9	.65	......	....	......
172	Randolph	Union City	....	1.23		83.21	12.48	......	2.14	.....
173	Starke	North Judson	......	.45	.74	89.92	2.46	......	1.56	......
174	Steuben	Hog lake	......	.14	.28	90.42	2.88	......	.68	......
175	"	Lime lake	......	....	*c*1.16	86	9.42	......	1.08	.....
176	"	Deep and Shallow lakes	.....	.04	.12	93.29	2.67	......	.47	......
177	"	James lake	.....	....	.29	92.41	2.38	......	1.16	......
178	"	Silver lake	......	......	*c*1.34	84	6.46	......	4.52	......
179	St Joseph	Notre Dame lake	......	....		91.25	3.21	....	3.8	......
180	"	"	......	.05	.07	91.62	4.02	......	.19	......
181	"	Chain and Bass lakes	....	.1	.2	87.92	2.64	....	3.1	......
182	"	Kankakee marsh	......	....	.08	91.3	2.9	......	.82	......
183	Wabash	Helms creek	34.2	18.76	*c*1.242	28	3.117	......	....	2
184	"	Lagro	35.6	17.86	*c*4.14	26	2.42	......	....	1.8
185	"	Wabash	......	7.58		53.18	30.53	......	3.52	......
186	"	Somerset	30.6	16.72	*c*2.48	25.6	12.713	.....	....	1
187	Washington	Salem	.76	.15		98.16	.97	.....	....	......
188	"	"	.76	.15		*a*54.97	.4 6	43.68	....	......
189	"	"	.63	......	.39	98.2	.39	.....	....	......
190	"	"	1.13	1.06		96.04	.72	......	....	.1
191	White	Rensselaer	.33	.14		56.28	43.26	......	....	......
192	Whitley & Noble	Loon lake	.....	.41	.42	82.07	2.63	......	5.95	......
193	Wells	Bluffton	.....	4.48		53.43	37.47	......	2.37	......
	Iowa									
194	Cedar	Near Rochester	.4	.1		78.75	20.16	....	....	......
195	Decatur	DeKalb	......	....		91.96	1.99	......	....	.07
196	Jackson	Monmouth	......	......	.53	57.54	41.51	......	.42	......
197	Marshall	LaGrande	......	.05		*a*55.05	*b*.28	43.62	.77	.13
198	"	"	......	.07		*a*54.85	*b*.28	43.3	.96	.21
199	"	"	.....	.18	.15	*a*50.56	*b*3.7	43.79	1.24	.15
200	"	"	......	.14	.15	*a*45.42	*b*8.21	44.85	.8	.19
201	"	"	.....	.15	.31	*a*45.39	*b*8.28	44.76	.89	.12
202	"	"	......	.14	.26	*a*50.42	*b*3.96	43.85	1.22	.12
203	Plymouth	On Big Sioux river south of Westfield	......	....		83.7	2.48	......	....	.06
204	"	Deep creek n. e. of LeMars	...	....		94.39	.7	....	....	.06
205	Sioux	Hawarden	.75	6.68		64.3	5.38	......	21.92	......
206	Allen	Humboldt	......	1.75		94.12	2.72	......	1.53	......

a C *b* MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCES AND ANALYST	OWNER LOCATION AND REMARKS
171	....	U. S. geol. sur. 20th rep't, pt 6, p. 381; W. A. Noyes anal.	Romona quarry. *see* no. 170
172	....	U. S. geol. sur. Bul. 148, p. 263; F. W. Clarke, anal.	Trenton limestone
173	Org. 4.51	Ind. geol. sur. 1900, p. 321; W. A. Noyes, anal	Marl
174	Org. 4.13	" " "	"
175	Org. 2.32	" " C. R. Dryer, anal..	"
176	Org. 1.56	" " W. A. Noyes, anal	"
177	$CaSO_4$ .15 Org. 1 97	" " "	"
178	Org. 3.68	" " C. R. Dryer, anal........	"
179	Org. 1.5	" p. 25; H. H.Hooper, anal......	"
180	$CaSO_4$ .14 Org. 2.25	" p. 381; W. A. Noyes, anal	"
181	$CaSO_4$ .23 Org. 4.18	" " "	"
182	$CaSO_4$ .22 Org. 3.88	" " "	"
183	loss 12.681	" 1891, p. 257...........................	Natural cement rock
184	loss 12.18	" 1891, p. 258...........................	"
185	....	U. S. geol. sur. Bul. 148, p. 263; C. Catlett, anal....	Trenton limestone
186	loss 10.887	Ind. geol. sur. 1891, p. 257...........................	Natural cement rock, Davis farm
187	....	U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Twin Creek quarry
188	....	U. S. geol. sur. 20th rep't, pt 6, p. 382; W. A. Noyes, anal.	" *see* no. 187
189	....	U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Hoosier quarry
190	Alkalis .15	U. S. geol. sur 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Salem quarry
191	....	U. S. geol. sur. 20th rep't, pt 6, p 381; W. E. Stone, anal.	Ind. macadam & construction co.
192	$CaSO_4$ .22 Org. 6.71	Ind. geol. sur. 1900, p. 321; W. A. Noyes, anal ...	Marl
193	....	U. S. geol. sur. Bul. 148, p. 263; C. Catlett, anal.....	Trenton limestone
194	MnO_2 .20	Iowa geol. sur. 11:336; N. Knight, anal	Lower Davenport limestone
195	....	" 8:308; J. B. Weems, anal	DeKalb limestone
196	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 383; S. Calvin, anal.	L. B. Stuart & Co.
197	FeO .09	Iowa geol. sur. 7:251; G. E. Patrick, anal.	Fine grained oolite, LaGrande quarry co.
198	FeO .27 MnO .08	" " " "	Blue limestone
199	FeO .09	" " " "	Iowa Caen stone
200	FeO .19	" " " "	Iowa marble, plain
201	FeO .1	" " " "	Iowa marble, colored
202	FeO .09 MnO trace	" " " "	Stratified limestone
203	....	" 8:359; J. B Weems, anal..........	Chalk rock, old quarries
204	....	" " " "	"
205	....	" 10:152	Benton limestone
206	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	

c Ferrous carbonate.

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Kansas									
207	Allen	Humboldt..........	......	5.91		91.02	.14	......	2.75	......
208	"	"	......	1.76		94.1	1.54	......	2.63	......
209	"	"	......	1.21		95.2	1.1	......	1.99	......
210	"	"	......	1.07		93.2	1.01	.....	3.79	......
211	Anderson.......	Garnett............	......	.81		92.76	.95	.....	4.3	.43
212	"	"	......	and FeO 1.51	......	97.32	.32	......	.61	......
213	Barber..........	....	......	1.95		94.62	1.4	......	1.85	......
214	Brown	Horton..............	......	5.53		81.91	1.56	.....	11.83	......
215	Butler	Eldorado	......	.96		93.32	1.06	.....	5.04	......
216	Chase...........	Strong City	......	1.05		90	1.6	.....	7.3	......
217	"	Cottonwood Falls...	......	3.62		84.72	1.75	.....	8.57	......
218	Cherokee	Galena	......	.69		97.32	.8	......	8	.....
219	"	Short Creek.........	.....	.17	......	a55.25	b.35	43.79	.32	......
220	Clay	Clay Center	......	6.4		60.04	24.72	......	9.57	......
221	Cowley.........	Silverdale	5.27	1.07	.71	a50.36	b.56	40.34	....	.78
222	"	Arkansas City.......	......	2.55		76.16	7.63	......	13.6	......
223	"	Winfield	......	.85		94.06	.62	......	4.25	......
224	"	Cambridge	......	1.69		93.98	.94	....	3.34	......
225	Douglas.........	Lawrence............	......	1.07		94.18	1.16	......	3.53	......
226	"	"	......	1.79		95.02	.79	......	2.29	......
227	"	"	......	2.05		88.54	1.29	......	8.02	......
228	Elk..............	Moline	.....	2.13		93 49	3.04	......	.66	......
229	Franklin........	Greeley	......	3.09		92.71	2.64	.....	1.18	......
230	"	Lane..................	......	2.38		94.77	1.07	......	1.18	......
231	"	"	......	& FeO .77	......	94.21	1.3	......	3.82	......
232	"	"	......	1.2		93.61	1.2	......	3.94	......
233	"	"	......	1.18		93.3	1.26	......	4.79	......
234	Hamilton.......	Coolidge..	......	3.07		90.63	.84	......	4.81	.08
235	Hodgeman	Jetmore	......	2.08		91.3	.87	......	5.06	.44
236	Jackson.........	....	......	2.02		83.99	2.66	......	10.93	......
237	Jefferson.......	Winchester..........	......	1.04		90.01	1.66	......	6.98	......
238	Johnson........	Ottawa	......	1.35		90	.12	.....	8	......
239	Leavenworth...	Lansing	......	2.47		89.88	1.11	.....	5.91	......
240	" ...	"	......	3.31		88.17	1.88	.....	6.2	.04
241	" ...	"	......	3.06		78.46	1.16	....	12.97	......
242	" ...	Soldier's Home......	......	4.09		69.07	3.06	......	17.49	......

aCaO

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
207	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Iola marble co.
208	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
209	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
210	Sulfates .2	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
211	" .23	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Carboniferous limestone
212	" .43	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	"
213	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
214	Sulfates .05	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Frey Bros. quarry
215	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Permian limestone
216	Sulfates .03	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Carboniferous limestone
217	" .9	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Bittiger Bros. quarry
218	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Subcarboniferous limestone
219	FeO .2 MnO .02	U. S. geol. sur. Bul. 168, p. 263; L. G. Eakins, anal.	Cherokee limestone
220	....	" 16th rep't, pt 4, p. 504	Permian
221	Alkalis .3 P_2O_5 .06 FeO .32 SO_3 .07	" Bul. 168, p. 263; C. Catlett, anal...	
222	....	" 16th rep't, pt 4, p. 504; Williston, anal.	Permian
223	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	"
224	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	H. Heddeman quarry
225	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Carboniferous
226	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
227	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
228	Sulfates .36	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
229	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
230	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Hanway quarry
231	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	"
232	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	"
233	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	"
234	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Benton Cretaceous
235	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
236	Sulfates .14	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	A. W. Charles quarry
237	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
238	Sulfates .02	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
239	Sulfates .38	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
240	Sulfates .28	U. S. geol. sur. 16th rep't pt, 4, p. 504; Williston, anal.	
241	Sulfates 2.32	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
242	Sulfates .37	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	

*b*MgO

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Kansas (*cont'd*)									
243	Marion	Marion	......	3.15		53.16	38.33	......	5.13	......
244	“	“	...	1.91		59.21	30.09	......	6.85	.9
245	“	“	......	1.65		61.64	22.72	......	13.51	......
246	“	“	......	1.59		51.05	40.51	....	6.75	......
247	“	“	......	1.24		91.5	1.62	......	5.51	......
248	Marshall.......	Beattie	......	4.29		80.1	1	..	13.89	......
249	“	“	......	2.37		84.8	2.8	......	8.75	.25
250	“	“	....	1.34		80.31	3.87	......	14.01	......
251	Micami	Fontana	......	.95		96.5	74	......	1.5	......
252	“	“	......	1.32		96.09	1	.....	1.35	......
253	“	“	......	.82		95.57	.8	......	2.44	......
254	Montgomery...	Independence	......	1.91		79.25	1.8	......	16.15	......
255	Nemaha	Sabetha	......	3.59		11.97	1.2	......	11.97	.29
256	Norton	Norton	......	& FeO .9		89	2	......	8.29	......
257	Trego	Wakeeney	14.06		5.1	*a*43.05	*b*.5	35.03	....	1.77
258	Wabaunsee.....	Alma	.....	1.74		89.68	1.99	......	6.22	......
259	“	“	.....	.7		88.55	1.25	......	9.12	......
260	“	“	.....	2.49		84.53	2.35	......	10.37	......
261	“	McFarland	......	2.61		92.5	1.62	......	3.27	......
262	Woodson	Yates Center........	......	2.6		88.03	2.04	....	6.8	......
	Kentucky									
263	Anderson.......	Lawrenceburg	......	& MnO_2 2.03		85.2	1.24	......	10.425	......
264	Barren..........	Glasgow Junction ..	......	& MnO_2 .511		98.05	.363	......	1.06	......
265	“	“ ..	......	& MnO_2 2.68		77.55	13.314	......	6.06	......
266	“	“ ..	......	& MnO_2 2.68		82.96	7.655	......	6.16	.....
267	Bath..........	W. side Clear creek..	......	& MnO_2 9.02		53.26	18.531	......	17.54	......
268	“	Near Owingsville....	......	& MnO_2 11.408		51.58	28.779	......	1.98	......
269	Bourbon	Quarry below woody pasture on William Buckner's land	......	& MnO_2 .542		96.51	1.049	......	1.886	......
270	“	Cane ridge, William Buckner's farm	......	& MnO_2 4.66		75.98	15.595	......	2.64	.....
271	“	5 m. e. of Paris	......	.38	5.51	71.14	11.826	......	2.27	......
272	Bullitt..........	Bellemot furnace...	......	& MnO_2 4.34		63.13	27.76	......	1.63	......

*a*CaO *b*MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
243	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Permian
244	Sulfates .95	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Carboniferous
245	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal	I. Kuhn & Co. Permian
246	....	U. S. geol. sur- 16th rep't, pt 4, p. 504; Williston, anal.	" "
247	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Permian
248	Sulfates .39	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
249	Sulfates .78	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal	
250	....	U. S. geol. sur. 16th rep't, pt 4, p 504; Williston, anal.	Carboniferous
251	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
252	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
253	....	U. S. geol. sur. 16 h rep't, pt 4, p. 505; Williston, anal.	
254	....	U. S. geol. sur. 16th rep't, pt 4, p 505; Williston, anal.	
255	Sulfates .55	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
256	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Loup Fork Tertiary
257	....	U. S. geol. sur. bul. 168, p. 263; F. W. Clarke, anal.	Supposed marl
258	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
259	....	U S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	A Zechser quarry, Carboniferous
260	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
261	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
262	Sulfates .21	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
263	P_2O_5 .185 SO_3 .17 Alkalis .79	Ky. geol. sur. chem rep't A, pt 2, p. 123	Lower Hudson River group
264	P_2O_5 .051 SO_3 .26 Alkalis .442	" " p. 119	Upper Subcarboniferous
265	P_2O_5 .051 SO_3 .192 Alkalis .342	" " p. 120	"
266	P_2O_5 .115 SO_3 .26 Alkalis .291	" " "	"
267	P_2O_5 .117 SO_3 .633 Alkalis .656	" " "	Lower Subcarboniferous
268	P_2O_5 .592 SO_3 .235 Fe_2CO_3 3.095 Alkalis .209	" " p. 122	Upper Silurian, Clinton group
269	P_2O_5 .138 SO_3 .18 Alkalis .249	" " p. 123..........	Lower Hudson group
270	P_2O_5 .822 SO_3 .427 Alkalis .207	" " p. 124	Trenton group
271	P_2O_5 .511 Loss .64 SO_3 .24	" " "	"
272	P_2O_5 .19 SO_3 3.77 Alkalis .59	" p. 121..........	Black Slate limestone

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Kentucky (*c'd*)									
273	Bullitt	H. C. Pindar's farm	......	& MnO_2 2.17		51.93	17.662	......	6.183	......
274	Butler	Barren river, mouth of Gasper creek	.....	& MnO_2 .917		93.02	2.088	......	2.76	......
275	Caldwell........	4 m. e. of Princeton	......	....		97.64	1.18	......	1.16	......
276	Carter	Mt Savage furnace.	......	& MnO_2 6.403		75.75	.575	.....	14.7	......
277	"	Iron Hills furnace ..	......	& MnO_2 1.39		95.15	.245	......	3.06	......
278	"	Willard..............	......	.98		96.38	1.135	......	.38	......
279	Clark...........	Quarry, mouth of lower Howard's creek	......	& MnO_2 3.28		85.56	3.567	......	5.92	......
280	"	Stewart's mill, Lulbegrud creek	......	....		21.38	3.055	......	27.58	......
281	"	Howard's creek.....	....	....		33.98	11.185	......	31.72	......
282	Crittenden	Crittenden furnace.	.....	& MnO_2 1.46		52.88	25.858	......	18.88	......
283	"	"	.....	& MnO_2 1.323		55.28	29.246	......	14.28	......
284	Estill	5 m. from Irvine on Richmond turnpike	......	& MnO_2 3.546		41.38	30.019	......	18.68	......
285	Fayette.........	Dan'l Brink's quarry	......	& MnO_2 3.98		91.48	1.044	......	2.38	......
286	"	Van Akin's quarry below Lexington	......	& MnO_2 2.42		92.73	.63	......	2.18	......
287	"	Van Akin's quarry below Lexington	......	& MnO_2 3.23		77.63	10	......	4.98	......
288	"	Grimes's quarry, nr. Grimes's mill	.....	& MnO_2 1.75		54.366	35.82	....	5.917	......
289	"	Harris's quarry, on Elk creek, 1 mile below Clays ferry.	.....	& MnO_2 1.38		59.88	37.05	......	2.68	......
290	"	Raven creek, Daniel Brink's quarry	......	& MnO_2 3.67		70.07	19.252	......	4.13	......
291	"	Dan'l Brink's quarry	......	& MnO_2 .38		95.68	2.044	......	1.58	......
292	"	Kentucky river bluffs	....	....		....	....	......	....	......
293	"	Newton turnpike, 6 m. from Lexington	......	....		....	....	......	....	......
294	"	Newton turnpike, at first tollgate	......	....		....	....	......	....	......
295	Fleming........	Hillsborough........	......	& MnO_2 12.434		42.68	25.358	......	10.88	......
296	Franklin........	Kentucky river bluffs	14.02	5.458	1.342	70.36	6.784	......	....	......
297	"	Near Bridgeport....	......	& MnO_2 1.19		92.65	1.54	....	3.68	......
298	"	"	......	& MnO_2 .769		95.38	1.51	......	2.08	......
299	"	Near Bright's mills..	......	& MnO_2 .124		89.625	.88	......	6.94	......
300	"	Big Benson creek ...	......	3.812		87.78	2.482	....	1.78	1.178
301	"	R. R. cut, 2 m. above Frankfort	.....	....		....	....	......	....	.....

*a*CaO *b*MgO

THE UNITED STATES *(continued)*

No.	Miscellaneous		Reference and Analyst	Owner Location and Remarks
273	Alkalis	.578	Ky. geol. sur. chem. rep't A, pt 2, p. 121..........	Upper Silurian, Niagara
274	P_2O_5	.243	" " p. 120..........	Upper Subcarboniferous
	SO_3	.604		
275	$FeO\&P_2O_5$	.28	" " p. 274..........	
276	P_2O_5	.057	" " p. 119..........	Coal Measures limestone
	SO_3	.775		
277	P_2O_5	.13	" " p. 120..........	Upper Subcarboniferous
278	$MnCO_3$	.953	" " p. 182..........	
279	P_2O_5	.118	" " p. 123..........	Trenton group
	SO_3	.474		
	Alkalis	.884		
280	P_2O_5	9.71	" " p. 279..........	Oriskany group
	Alkalis	1.058		
281	P_2O_5	1.842	" " "	"
282	P_2O_5	1	" " p. 120..........	Lower Subcarboniferous
	SO_3	.003		
	Alkalis	.649		
283	Alkalis	.4	" " "	"
284	SO_3	1.471	" " p. 121..........	Upper Silurian, Niagara
	P_2O_5	3.74		
	Alkalis	.501		
285	P_2O_5	.848	" " p. 123..........	Trenton group
	SO_3	.317		
	Alkalis	.568		
286	P_2O_5	.86	" " p. 124..........	"
	SO_3	.34		
	Alkalis	.51		
287	P_2O_5	.7	" " "	"
	SO_3	3.12		
	Alkalis	.47		
288	P_2O_5	.31	" " "	"
	SO_3	.23		
	Alkalis	1.57		
289	Alkalis	1.03	" " "	"
290	P_2O_5	.246	" " "	"
	SO_3	.303		
	Alkalis	.45		
291	P_2O_5	.182	" " p. 125..........	Birdseye limestone
	SO_3	.166		
	Alkalis	.241		
292	P_2O_5	11.65	" " p. 259..........	Phosphatic
293	P_2O_5	3.88	" " p. 375..........	" Trenton
294	P_2O_5	3.487	" " "	"
295	P_2O_5	.843	" " p. 122..........	Clinton limestone
	Alkalis	.323		
	Fe_2O_3	5.155		
	SO_3	.324		
296	Alkalis	1.399	" " p. 93..........	Trenton group
297	P_2O_5	.09	" " p. 123..........	Lower Hudson River group
	SO_3	1.27		
	Alkalis	.43		
298	P_2O_5	.311	" " p. 124..........	Trenton group
	SO_3	.579		
	Alkalis	.141		
299	P_2O_5	.41	" " "	"
	SO_3	.680		
	Alkalis	.52		
300	P_2O_5	2 968	" " p. 259..........	Phosphatic; Lower Trenton
301	P_2O_5	4.029	" " p. 315..........	" Trenton group

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Kentucky (*c'd*)									
302	Garrard	Burdett's Knob	......	& MnO_2 5.2		34.78	21.47	....	35.18	......
303	Grayson........	Falls of Rough creek	......	& MnO_2 2.56		85.68	2.503	......	7.48	......
304	Greenup........	Pea ridge	......	& MnO_2 3.76		88.41	.797	....	5.96	.....
305	"	Buffalo cr., Boome furnace	.....	& MnO_2 4.167		60.75	25.656	.....	5.68	.....
306	"	Head of Old Town creek	......	& MnO_2 .152		88.15	.285	....	9.56	.....
307	"	Kenton furnace.....	......	& MnO_2 1.49		92.05	.22	......	4.46	.....
308	Hardin	Sinking creek	......	& MnO_2 .88		79.18	11.469	....	6.98	.....
309	"	Mr Moreman, 1½ m. s. of Big Spring	.....	& MnO_2 .46		98.58	.629	......	.38	.....
310	Harlan.........	½ m. from Creech postoffice	1.38	4.8		59	1.82	....	16.36	......
311	Henderson	Mount Zion	......	& MnO_2 1.76		88.38	3.678	....	3.28	......
312[1]	Indiana[1].......	Madison quarries[1]..	.....	5.76		45.88	22.911	......	21.52	......
313	Jefferson	Louisville	......		2.93	50.43	18.67	......	25.78	......
314	"	Farm of Theodore Brown	......	& MnO_2 1.48		89.06	6.783	......	2.68	......
315	"	Farm of Theodore Brown	......	& MnO_2 .48		92.56	4.615	......	2.58	.....
316	"	Farm of Theodore Brown	......	& MnO_2 .726		87.78	7.096	......	3.48	......
317	Lewis...........	Vanceburg..........	1.15	2.49		48.79	37.482	.....	8.85	.547
318	Lyon	Near Eddyville	.....	.68		85.58	2.088	......	9.58	1.643
319	Madison........	Muddy creek, nr. J. R. Compton	......	& P_2O_5 10.33		48.53	11.79	......	20.74	&loss 6.567
320	"	Mill dam, Muddy creek, Elliston	20.98	17.656	3.7	37.76	10.05	...	25.18	&loss 4.902
321	"	Muddy creek	22.8	21.256	4.12	33.56	6.855	......	29.08	&loss 4.302
322	"	Below mill dam, Muddy creek	......	& P_2O_5 11.36	3.5	45.7	27.475	......	9.98	&loss 1.396
323	"	Below mill dam, Muddy creek	......	& P_2O_5 9.96	3.9	50.86	20.1	......	3.98	&loss 10.87
324	"	Below mill dam, Muddy creek	......	& P_2O_5 5.96	3.56	50.96	27.972	......	4.12	&loss 6.493
325	"	Below mill dam, Muddy creek	......	12.36	4.46	51.2	25.124	......	3.92	&loss 2.46
326	"	Quarry north of Rogersville	.....	10.706	2.06	35.16	4.646	......	39.78	&loss 4.275
327	"	Near Elliston........	......	& P_2O_5 9.42	2.64	43.06	9.994	......	22.68	&loss 11.287
328	"	"	......	& P_2O_5 9.04	1.89	41.15	13.908	......	20.99	Etc. 13.022
329	"	1 m. s. of S. J. Embry's	......	& P_2O_5 10.98		47.58	17.133	......	18.19	&loss 6.117
330	"	Crittenden furnace.	......	& MnO_2 9.46		40.28	15.903	......	23.18	.....
331	"	Elliston, Covington's farm	......	& MnO_2 2.96		49.32	30.729	......	14.18	......
332	"	....	.....	4.01 & P_2O_5 1.54		36.58	18.541	......	....	......

[1] Misplaced. Should be Madison. Jefferson co. Indiana.

THE UNITED STATES (*continued*)

No.	Miscellaneous		Reference and analyst	Owner Location and remarks
302	P_2O_5 SO_3 Alkalis	.31 .956 .601	Ky. geol. sur. chem. rep't A, pt 2, p. 121........	Upper Silurian
303	P_2O_5 SO_3 Alkalis	.182 .839 .359	" " p. 120........	" Subcarboniferous Coralline
304	P_2O_5 SO_3 Alkalis	1.78 .044 .509	" " p. 119........	Coal Measures limestones
305	Fe_2CO_3 P_2O_5 SO_3	3.42 .013 .315	" " "	"
306	P_2O_5	.051	" " p. 120........	Upper Subcarboniferous
307	P_2O_5 SO_3	.123 .199	" " "	"
308	P_2O_5 SO_3 Alkalis	156 .338 .271	" " "	"
309	P_2O_5 SO_3 Alkalis	.125 .274 .176	" " "	"
310	Org.	16.64	" " p. 283........	Carboniferous limestone
311	P_2O_5 SO_3 Alkalis	.246 .166 .357	" " p. 119........	Coal Measures limestone
312	P_2O_5 Alkalis	.22 .719	" " p. 93........	
313	Alkalis	.45	" " "	
314	P_2O_5 SO_3 Alkalis	.31 .475 .317	" " p. 121........	Upper Silurian
315	SO_3 Alkalis	.166 .236	" " "	"
316	P_2O_5 SO_3 Alkalis	.386 .358 .281	" " p. 122........	Clinton group. Layer next to top
317	P_2O_5 Alkalis	.143 .548	" " p. 289........	
318	Alkalis	.429	" " p. 291........	
319	....		" " p. 57........	Clinton shaly limestone
320	P_2O_5	.204	" " "	"
321	....		" " "	Impure limestone
322	....		" " "	" on Cumberland shale
323	....		" " "	Niagara. Top stratum
324	FeS_2	.576	" " "	Second stratum from top
325	P_2O_5	.14	" " "	Niagara. Third stratum from top
326	P_2O_5	.754	" " "	Clinton limestone
327	....		" " "	From below Cauda-galli grit
328	....		" " "	Bituminous limestone above Corniferous
329	....		" " "	
330	SO_3 Alkalis	1.025 .6	" " p. 121........	Black Slate limestone
331	Alkalis	.43	" " "	"
332	....		" " "	Corniferous

*a*CaO *b*MgO L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Kentucky (*c'd*)									
333	Mason..........	Near boundary with Fleming co.	......	& MnO_2 3.751		75.44	4.783	......	14.44	......
334	"	Mason co. tobacco land	......	& MnO_2 2.2		87.98	1.721	......	6.38	......
335	"	Near boundary with Fleming co.	.....	& MnO_2 3.91		77.36	2.307	......	13.98	......
336	Mercer	Near Cornishville...	......	& MnO_2 2.34		88.9	1.468	......	7.185	......
337	"	Farm of James C. McAfee	......	& MnO_2 2.7		90.72	4.615	......	1 88	......
338	"	No. 1 } No nearer location given	......	& MnO_2 1.22		62.86	30.72	.....	5	......
339	"	No. 2 }	......	& MnO_2 .98		83.58	10.55	......	5.56	......
340	"	Kentucky river bluffs	......	1.22		62.86	30.72	......	5	
341	"	Kentucky river bluffs	......	10.55		83.04	10.55	......	5.56	2.3
342	Montgomery....	L. C. Jeffries farm, Aaron run	......	....	....	....	....	.....	....	......
343	Muhlenberg ...	Arsdie furnace	......	& MnO_2 4.333		82.88	4.196	......	4.26	.....
344	Nelson	Nelson's furnace....	......	& MnO_2 5.55		51.66	32	......	9.78	.....
345	"	Troutman's	.....	& MnO_2 2.1		50.48	38.154	......	8.38	......
346	"	Rolling Fork	......	& MnO_2 3		49.78	34.456	......	10.78	......
347	"	Bardstown	......	2.978		81.58	1.501	......	11.12	......
348	"	"	......	4.317		61.24	8.915	......	22.52	......
349	Nicholas	R. R. cut, Carlisle..	......	& MnO_2 2.48		78.68	1.566	......	16.64	......
350	Ohio............	3 m. below Hartford	......	& MnO_2 8.64		41.68	22.748	....	24.06	......
351	Owen...........	Harmony...........	......	& MnO_2 3.58		92.92	.559	......	1.72	......
352	Shelby	5 m. s. e. Shelbyville	......	5.917		40.78	24.511	......	25.12	2.168
353	Spencer.........	Upper Hudson river beds	......	2.478		87.32	.787	......	1.68	5.527
354	Warren	....	.76	....	.22	*a*54.8	tr.	33	....	.38
355	Woodford......	Near Versailles	......	& MnO_2 1.04		96.24	.945	......	.78	......
356	"	"	......	& MnO_2 1.53		91 33	.56	......	5.18	......
357	"	Hills at Shyrocks ferry	......	& MnO_2 .63		94.75	1.96	.....	2.18	......
358	"	Shyrocks ferry......	......	& MnO_2 .98		59.86	36.64	....	2.48	.....
	Louisiana									
359	Bienville........	Rayborn's Salt Lick	.55	1.61		*a*54.09	*b*.06	44.12	....	.05
360	Winn	5 m. w. of Winnfield	......	trace	......	*a*55.01	*b*.6	43.43	65	.13

*a*CaO *b*MgO

THE UNITED STATES *(continued)*

No.	Miscellaneous	Reference and analyst	Owner location and remarks
333	P_2O_5 .409 SO_3 .474 Alkalis .832	Ky. geol. sur. chem. rep't A, pt 2, p. 123..........	Upper Hudson. Oxidized
334	P_2O_5 .348 SO_3 .372 Alkalis .336	" " "	" "
335	P_2O_5 .31 SO_3 2.433 Alkalis .492	" " "	" "
336	P_2O_5 .631 SO_3 .235 Alkalis .221	" " "	Lower Hudson. Under subsoil of old field
337	Alkalis .349	" " p. 124..........	Trenton
338	....	" " p. 125..........	Chazy limestones
339	....	" " "	"
340	....	" " p. 259....	" see no. 338
341	....	" " "	" see no. 339
342	P_2O_5 .473	" " p. 315..........	Phosphatic limest. of Trenton
343	SO_3 4.717 P_2O_5 .247 Alkalis .285	" " p. 119..........	Coal Measures limestone
344	SO_3 .09 Alkalis 1 23	" " p. 121..........	Black-slate limestone
345	P_2O_5 .118 SO_3 .289 Alkalis .518	" " p. 122....	Upper Silurian
346	P_2O_5 .246 SO_3 .475 Alkalis .276	" " "	" "
347	P_2O_5 1.202 Alkalis .671	" " p. 222..........	Upper Hudson river
348	P_2O_5 .563 Alkalis .697	" " "	"
349	P_2O_5 .247 SO_3 .27 Alkalis .345	" " p. 123..........	Lower Hudson river
350	P_2O_5 .153 Alkalis 1.576	" " p. 119..........	Coal Measures limestone
351	P_2O_5 .349 SO_3 .338	" " p. 123..........	Lower Hudson river
352	P_2O_5 .563 SO_3 .941	" " p. 259....	Upper Silurian
353	P_2O_5 1.842 Alkalis .366	" " "	
354	Alkalis 6.48	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 388	Caden stone co.
355	P_2O_5 .63 SO_3 .178 Alkalis .87	Ky. geol. sur. chem. rep't A, pt 2, p. 123	Lower Hudson river
356	P_2O_5 .7 SO_3 .33 Alkalis .77	" " p. 124...........	Trenton limestone
357	P_2O_5 trace SO_3 .3 Alkalis .262	" " p. 125...........	Birdseye limestone
358	SO_3 .16 Alkalis .48	" " "	Chazy limestone
359	SO_3 .05	U. S. geol. sur. Bull 168, p. 258; R. B. Riggs, anal..	
360	....	U. S. geol. sur. Bull 168, p. 258; W. F. Hillebrand, anal.	White marble, black streaks

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Maine									
361	Knox	Rockland..........	1.08	.07	......	*a*54.97	*b*.04	43.25	....	......
362	"	Union...............	1	....		95.2	1	......	....	2.7
363	"	Warren.............	.95	....		53.52	45.13	.....	....	.4
	Maryland									
364	Allegany.	Cumberland........	24.74	16.74	6.3	41.8	8.6	.....	....	......
365	Baltimore......	Cockeysville........	......	.4		*a*20.08	*b*20.3	44.26	5.57	......
366	Frederick......	Walkersville........	4.73	1.4		93.57	.34	......	....	......
367	"	"	4.31	.9		81.97	13	......	....	.....
368	"	Frederick..........	.22	.29	.25	97.32	2.08	.....	....	......
369	"	"	.1	.16	trace	96.79	2.86	......	....	......
370	Washington....	Cavetown...........	.47	....		*a*55.51	....	.....	....	......
371	"		5.8	.1		*a*50.79	*b*1.57	41.58	....	......
372	"		.25	....		*a*56.18	*b*1.31	44.01	....	......
373	"		2.4	.6		*a*53.07	*b*1.07	42.87	.. ..	......
374	"		3	.27		*a*30.21	*b*20.37	46.06	....	......
375	"	Specimens from different places in Hagerstown Valley	.7	....		*a*30.76	*b*21.12	47.4	....	......
376	"		2	.64		*a*31.64	*b*14.69	41.03	....	......
377	"		.6	....		*a*55.18	*b*.41	43.81	....	......
378	"		6	.2		*a*50.79	*b*1.43	41.48	....	......
379	"		.2	.1		*a*54 32	*b*1.19	43.99	....	......
380	"		2	.3		*a*53.2	*b*1.24	43.16	....	......
	Massachusetts									
381	Berkshire......	Renfrew	.63	.55		99.6	.49	......	....	......
382	"	" L	.36	.15	......	*a*98.13	*b*.42	.6	....	.2
383	"	" L	.81	.47		*a*96.63	*b*.88	.12	....	......
384	"	Cheshire	.31	.23		98.8	.37	.35	....	......
385	"	New Lenox........L	1.14	.17		*a*95.66	*b*.76	......	....	......
386	"	West Stockbridge...	......	....		99.029	.266	......	....	......
387	"	Lee.................	.95	.09	......	*a*54.75	*b*.56	43.38	....	.08
388	Franklin........	Charlemont.........	.67	trace	.08	*a*28.63	*b*16.17	45.35	....	......
389	Worcester......	Webster............	1.01	.17	.....	*a*30.82	*b*21.35	45.84	....	.09

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
361	FeO .08	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 398; F. C. Robinson, anal.	J. H. McNamara quarry
362	FeO trace	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 398; F. C. Robinson, anal.	G. W. Bachelder
363	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 398; S. P. Sharpless, anal.	McLoon & Stover lime co.
364	....	Md. geol. sur. Allegany co. rep't, p. 186.	Salina group
365	....	U. S. geol. sur. Bul. 168, p. 253; E. A. Schneider, anal.	
366	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 401; H. J. Patterson, anal.	J. W. Stimmel, no. 1
367	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 401; H. J. Patterson, anal.	J. W. Stimmel, no. 2
368	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 401; J. O. Hargrove, anal.	M. J. Grove lime co. (dark stone)
369	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 401; J. O. Hargrove, anal.	M. J. Grove lime co. (light stone)
370	Loss on ign. 44.02	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 401; Lehman & Glaser, anal.	P. G. Zouck & Co.
371	Und. .12	Md. geol. sur. 1898, p. 197; Dr J. Higgins, anal.....	Limestones of Shenandoah formation
372	Und. .25	" " "	Limestones of Shenandoah formation
373	....	" " "	Limestones of Shenandoah formation
374	....	" " "	Limestones of Shenandoah formation
375	....	" " "	Limestones of Shenandoah formation
376	....	" " "	Limestones of Shenandoah formation
377	....	" " "	Limestones of Shenandoah formation
378	....	" " "	Limestones of Shenandoah formation
379	Und. .3	" " "	Limestones of Shenandoah formation
380	Und. .1	" " "	Limestones of Shenandoah formation
381	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 410; E. E. Olcott anal.	Adams marble co.
382	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 410; P. S. Burns, anal.	J. Follett & Sons
383	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 410, H. P. Eddy, anal.	J. Follett & Sons
384	Org. .35	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 410; Davenport & Williams, anal.	Cheshire mfg co.
385	Ign. 3	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 411; W. M Habirshaw, anal.	Hutchinson Bros.
386	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 411; J. B. Britton, anal.	C. H. Hastings
387	Alkalis .17 P_2O_5 .03 FeO .1	U. S. geol. sur. Bul. 168, p. 252; G. Steiger, anal..	Cut on west side of railroad
388	FeO 7.6	U. S. geol. sur. Bul. 168, p. 252; L. G. Eakins, anal.	
389	Alkalis .11 FeO .37 P_2O_5 .06	" " " H. N. Stokes, anal.	

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Michigan									
390	Alpena..........	Alpena..............	......	trace		93.54	1.24	......	....	......
391	"	" L	1.96	.94		a95.6	b.14	......	....	& CO_2 1.36
392	"	" L	3.42	1 21		a94.26	b.32	.....	....	& CO_2 .79
393	Charlevoix......	Bayshore L	1.09	1.74		a81.83	b13.42	......	....	& CO_2 1.92
394	"	" L	.7	.66		a96.8	b.67	......	....	& CO_2 1.17
395	Emmet..........	Petoskey............	......	....		87.65	11.22	......	....	......
396	Huron..........	Bayport.............	3.33	1.334		91.538	.944	......	....	......
397	Monroe	2 m. n. e. of Dundee	.48	......	.16	90.8	6.87	.....	....	......
398	"	"	1.1	......	.12	86.8	11.6	......	....	......
399	"	"	2.78	......	.56	77.6	17.41	......	....	......
400	"	"	.81	......	.41	95	3.86	......	....	......
401	"	"	.7	....		98.1	.63	......	....	......
402	"	"	1.86	.62		86.96	10.08	......	....	......
403	"	Lulu.................	......	....		54	42	......	4	......
404	"	2. m. n. of Monroe city	2	.7		54.54	42.75	.....	....	......
405	"	2. m. n. of Monroe city	.74	.98		54.47	43.59	......	....	......
406	"	2. m. n. of Monroe city	1.33	.58		54.94	42.84	......	....	......
407	"	n. e ¼, s. w ¼, sec. 8, Ash township	.....	.48		55.03	42.17	.....	2.32	......
408	Wayne...... ...	Trenton	.6	.06		98.53	.53	......	....	......
409	"	"	.4	.08		97.5	1.26	.....	....	......
	Minnesota									
410	Dodge..........	Mantorville.........	......		1.77	50.2	38.96	......	6.33	......
411	Fillmore	Fountain...........	......	1.3		86.107	.47	......	9.89	......
412	"	Lanesboro	......	.33	.37	49.66	42.06	......	3.45	......
413	"	"	......	1.05		62.14	28.49	......	7.35	......
414	Goodhue.......	Frontenac..........	......	.31	.36	54.78	42.53	......	2.93	......
415	"	Red Wing...........	....	.37	.55	50.68	33.61	......	....	......
416	Hennepin	Minneapolis	......	......	4.03	41.88	24.55	......	29.93	......
417	"	"	.....	3.16	.9	54.533	36.002	......	16.22	......
418	"	"	......	1.7		75.482	6.81	......	14.45	......
419	Lesueur........	Kasota	.....	1.09		49.16	37.53	......	13.06	......
420	"	"	......	......	1.49	47.904	35.227	.....	13.85	......
421	Ramsey	St Paul.............	......	2.67	1.63	79.18	6.42	......	13.39	......
422	Steele...........	Clinton Falls	......	1.94		57.08	15.9	......	25.51	......
423	Washington ...	Stillwater...........	......	.64	.78	50.22	37.39	.....	8.54	......
424	Winona.........	Winona	......	.96		51.23	41.33	......	6.32	

a CaO b MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	LOCATION AND REMARKS
390	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 412......	R. Collins quarry
391	....	" " p. 413......	
392	....	" " "	
393	....	" " " ...... E. J. Schneider, anal.	Petoskey lime co.
394	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 413; E. J. Schneider, anal.	"
395	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 412; Strong & Dunham, anal.	H. O. Rose quarry
396	Org. & loss 2.854	Mich. geol. sur. 7, pt 2, p. 214	
397	Org. 1.69	" pt 1, p. 76; G. A. Kirschmeier, anal.	B. E. Bullock quarry
398	....	" " "	"
399	Org. 1.63	" " "	"
400	....	" " "	"
401	S .055	" " K. J. Sundstrom, anal.	"
402	S .123	" " "	"
403	....	" p. 87........................	H. McCarthy quarry
404	....	" p. 95; K. J. Sundstrom, anal	Monroe stone co.
405	....	" " "	"
406	....	" " "	"
407	....	" p. 92 "	
408	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 412	Sibley quarry co.
409	....	" " "	"
410	....	G. P. Merrill, Stones, for bld'g and decoration, p. 467	Hooke's quarry
411	....	" " "	
412	....	" " "	Mill co. quarry
413	....	" " "	
414	....	" " "	
415	....	" " "	Sweeney's quarry
416	....	" " "	Foley & Herbert quarry
417	....	" " "	Weekes & Hoschers quarry
418	....	" " "	Eastmans quarry
419	....	" " "	
420	....	" " "	Breckenridge Bros. quarry
421	....	" " "	A. Raus's quarry
422	....	" " "	
423	....	" " "	Hersey & Co. quarry
424	....	" " "	

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Minnesota (*c'd*)									
425	Winona	Gunflint lake........	2.7	.35	7.23	49.8	16 65	......	....	.47
426	....	Ogiskemannissi lake	41.99	1.24	.42	*a*16.85	*b*8.41	24.7	MnO .26	1.07
	Mississippi									
427	Chickasaw	Okolona............	......	1.957	1.421	81.77	.877	....	10.903	......
	Missouri									
428	Greene.........	Ash Grove.........L	.12	.054	.011	*a*99.815	trace	......	....	......
429	"	"	.....	.48	.4	92.75	3.26	.....	.495	.675
430	"	Springfield	.33	....	.21	99.46	....	.....	....	......
431	Jasper	Sarcoxie	.....	.88	.05	98.34	trace	......	.42	......
432	"	Joplin	.....	1.32		*a*21.46	*b*14.79	33.13	29.77	......
433	Marion	Hannibal	.08	.4		98.8	.02	......	....	......
434	Newton.........	Seneca	......	.11	......	*a*55.29	*b*.23	43.69	.66	......
435	"	"	......	.13	.....	*a*54.92	*b*.2	43.31	1.21	......
436	"	Grand Falls.........	......	.08	......	*a*54.98	*b*.31	43.54	1.01	......
437	"	"	......	.13	.....	*a*55.11	*b*.32	43.65	1.01	......
438	Ralls............	Hannibal	......	....		99.64	.21	......	.15	......
439	St Louis	Glencoe	......	.68		98.36	*b*.26	......	.7	......
440	"	....	......	......	.2	97.76	.12	....	.26	......
	Montana									
441	Lewis & Clarke	Helena	1.45	.16	.76	88.25	5.7	......	....	......
442	"	N. of East Gallatin river	.....	.22		54.54	43.63	......	.34	......
443	"	W. of North Boulder river	.....	.4		54.54	42.62	......	1.78	......
444	"	N. of East Gallatin river	......	2 5		67.85	6.18	.....	23.5	......
445	"	N. of East Gallatin river	.....	1.92		59.11	1.96	....	35.26	......
446	"	West side Bridger range	......	.38		88.5	.95	....	9.98	......
447	"	N. of Gallatin river..	......	.58		91.96	1.35	......	5.99	......
448	"	" ..	......	.3		32.28	13 91	.....	50.74	......
449	"	" ..	....	5.3		40.21	25 25	.....	25.24	....
	Nevada									
450	Eureka	Eureka	.....	....		*a*30.6	*b*21.69	47.13	.53	......
451	"	"	24	.12	.12	*a*41.97	*b*.8	32.62	....	.16
452	"	"	3.94	64	.43	*a*51.96	*b*.52	40.71	....	.37
453	"	"	9 34	.31	.29	*a*50.01	*b*.54	39.11	Org. tr.	.13
	New Jersey									
454	Hunterdon	Annandale	.....	.98		*a*28.27	*b*15.3	38 88	16.9	......
455	"	Amsterdam	......	1.4		*a*46.6	....	36.6	14.1	......
456	"	Clinton	......	1.9		*a*27.7	*b*17.4	43	7.2	......

*a*CaO *b*MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
425	FeO 3.85 SO_3 .32	U. S. geol. sur. Bul. 148, p. 265	
426	FeO 4.77	" " " T. M. Chatard, anal.	
427	K_2O .248 Ign. 2.84 Na_2O .321	Ark. geol. sur. 1888, p. 237	"Rotten Limestone"
428	....	Min res. 1889–90, p. 407; C. W. Eoff, anal..........	
429	Alkalis 1.94	" " W. D. Church, anal......	
430	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 415; R. Chauvenet & Bro. anal	Marble Head lime co.
431	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 415.......	"
432	....	" Bul. 168, p. 263; L. G. Eakins, anal.	
433	....	" 20th rep't, pt 6 cont'd, p. 415	Hannibal lime co.
434	MnO trace FeO .05	" Bul. 168, p. 263; L. G. Eakins, anal..	Cherokee limestone
435	MnO trace FeO .07	" " " "	"
436	MnO .03 FeO .05	" " " "	"
437	MnO trace FeO "	" " " "	"
438	....	" 20th rep't, pt 6 cont'd, p. 415.......	Star lime co.
439	....	" " " "	Glencoe lime and cement co.
440	....	Min. res. 1889–90, p. 407............................	
441	....	U. S. geol sur 20th rep't, pt 6 cont'd, p. 416.......	Persell limestone co.
442	....	" Bul. 168, p. 269; C. Catlett, anal ...	
443	....	" " " "	
444	....	" " " "	
445	....	" " " "	
446	....	" " " "	Base of Carboniferous
447	....	" " " "	Middle Carboniferous
448	....	" " " "	Upper Carboniferous
449	....	" " " "	"
450	....	" " p. 276; E. A. Schneider, anal.	
451	P_2O_5 .07	U. S. geol. sur. Bul. 168, p. 276; W. F. Hillebrand, anal.	Base of Hamburg limestone
452	FeO .2 MnO .61 P_2O_5 .5	U. S. geol. sur. Bul. 168, p. 276; W. F. Hillebrand, anal.	Summit "
453	P_2O_5 .24	U. S. geol. sur. Bul. 168, p. 276; W. F. Hillebrand, anal.	Pogonip limestone (Silurian)
454	....	N. J. geol. sur. 1900, p. 33	Gano's quarry
455	....	" 1868, p. 393	W. Vanderbilt farm
456	....	" " "	Light gray, S. H. Leigh quarry

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	N. Jersey (*c'd*)									
457	Hunterdon.....	Clinton..............	......	3.7		*a*26.4	*b*15.1	45	9.8	......
458	"	"	......	6.5		*a*27.3	*b*14.6	44.8	4.9	......
459	"	"	......	.84		*a*29.8	*b*19.93	......	7.23	......
460	"	Newton.	.....	1.1		*a*28.61	*b*20.52	44.88	5.9	......
461	"	"	......	1.06		*a*29.62	*b*20.63	......	4.92	......
462	"	"	......	1.4		*a*30.13	*b*21.71	.....	1.95	......
463	"	New Germantown ..	......	6		*a*21.2	*b*13.2	31.3	25.8	& loss 2.5
464	"	Near Pattenburg....	8.42	2.3	......	*a*44.64	*b*.36	34.47	....	......
465	"	"	18.6	5.8	......	*a*38.76	*b*.66	31.2	....	......
466	"	Pennwell...........	.....	....	....	*a*29.87	....	.....	2	......
467	"	"	......	....	....	*a*29.64	....	......	2.8	......
468	"	"	......	....	....	*a*25.75	....	....	1.9	......
469	"	"	......	....	....	*a*26.65	....	....	4.1	......
470	"	Vernoy	2.28	.545	1.34	52.45	43.25	......	....	......
471	"	Middletown[1]	......	.75		*a*49.1	*b*1.13	......	10.49	......
472	Morris..........	Mendham, 1 m. e....	.....	1.6		*a*33.95	*b*18.21	27.66	16.4	......
473	"	"	......	15.7		*a*23.74	*b*16.82	26.2	14.7	& loss 2.84
474	"	Montville............	......	.8		*a*30.41	*b*19.29	42.6	4.8	.9
475	Passaic..........	Macopin.............	......	2.2		*a*29.5	*b*20.3	45.6	1.1	1
476	"	Middle Forge........	......	9.7		*a*27.3	*b*18.1	42	4	......
477	"	West Milford.........	......	1.8		*a*29.6	*b*20.3	45.5	2.7	......
478	Salem	Mannington township	23.31	.91	3.07	69.61	*b*1.81	.....	....	.24
479	"	Swede's Bridge	8.11	.86	3.56	84.73	*b*1.4	......	....	.45
480	Somerset.......	Pepack	......	4	1.3	*a*26.3	*b*17.4	41.1	8	.7
481	"	"	......	1.6		*a*30.3	*b*18.3	44.1	4.1	......
482	"	"	......	3		*a*31.6	*b*18.3	45.2	1.6	....
483	"	Pottersville	......	8.4		*a*32.4	*b*15.5	42.5	2	......
484	Sussex	Andover	......	.45		*a*55.13	......	43.32	.85	.....
485	"	"	......	.7		*a*52.41	trace	41.19	5.7	......
486	"	"	......	.6		*a*52.41	trace	41.19	5.5	......
487	"	"	......	5.9		*a*49	*b*2.88	38.5	.9	1.8
488	"	Beaver Run..........	......	.38	......	*a*54	*b*1	......	2.62	......
489	"	"	......	1.48	......	*a*46.66	*b*.31	.....	14 27	......
490	"	"	....	1.14		*a*53.64	*b*.81	42.72	2.54	......
491	"	e. of Beaver Run ..	......	1.03		*a*47.8	*b*1.35	.....	13	......
492	"	Branchville	....	.6		*a*48.6	*b*4.2	43.9	2.6	......
493	"	Carpenter's Point...	8.5	16.9		*a*39.87	*b*1.42	33.31	....	.6

Analyses 460, 461, 462 and 471 should have been placed under Sussex co.

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
457	....	N. J. geol. sur. 1868, p. 393	Average from Leigh's quarry
458	....	" " "	J. Mulligan & Bro. quarry
459	....	" 1900, p 33	"
460	....	" " "	O'Donnell & McManniman quarry
461	....	" " "	O'Donnell & McManniman quarry
462	....	" " "	O'Donnell & McManniman quarry
463	....	" 1868, p. 393	Calcareous conglomerate
464	....	" 1900, p. 50	Trenton limestone
465	....	" " "	"
466	....	" 1878, p. 105	J. Warner quarry. Blue magnesian limestone
467	....	" " "	J. Warner quarry. Blue magnesian limestone
468	....	" " "	J. Warner quarry. Blue magnesian limestone
469	....	" " "	J. Warner quarry. Blue magnesian limestone
470	Phos. .035	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 420; H. Weaver, anal.	E. Weise estate
471	....	N. J. geol. sur. 1900, p. 58	Trenton limestone
472	....	" 1878, p. 104	Crystalline limestone. Saunders quarry
473	....	" 1868, p. 402	Serpentine limestone
474	....	" " p. 401	Turkey mountain, Boonton iron co.
475	....	" " p. 393	Average, R. Gould quarry
476	....	" " "	
477	....	" " p. 393	D. Cisco quarry
478	....	" " p. 441	Yellow limestone
479	....	" " "	Limesand. Pit of J. Fowler
480	....	" " p. 392	Drab stone. H. Hilliard quarry
481	....	" " "	Best of M. Craig quarry
482	....	" " "	Average selected sample
483	....	" " "	
484	....	" " p. 403	White limestone, hill north of Andover, Boonton iron co.
485	....	" " "	White limestone, hill north of Andover, Boonton iron co.
486	....	" " "	White limestone, hill north of Andover, Bo nton iron co.
487	....	" " p. 479	Shell marl, J. J. Decker's, 1 m. s. w. of Andover
488	....	" 1900, p. 70	Webster Kernick's farm
489	....	" " "	"
490	....	" " 71	J. B. Hardens
491	....	" " 70	F. Kemble's farm
492	....	" 1868, p. 398	Fossiliferous, ⅛ m. n. e. of Branchville
493	....	" " p. 399	Firestone. Nearpass quarry

*a*CaO *b*MgO L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
494	N. Jersey (*c'd*) Sussex	Carpenter's Point...	4	1.1		*a*52.52	*b*.33	41.8	....	......
495	"	" ...	22.8	8.94	2.57	*a*20.44	*b*12.08	31.06	....	1.1
496	"	" ...	4.1	.9		*a*52.92	.....	41.58	....	......
497	"	" ...	....	1.1		*a*51.52	.....	40.5	5.3	......
498	"	Centerville....	......	....	....	64.2	......	.. ..	16.21	16.59
499	"	Chandler's island ..	.....	1.1	.6	*a*27.6	.9	41.9	9.9	.2
500	"	Dingmans Ferry....	.93	6.5		*a*50.79	*b*.44	40.37	....	.8
501	"	Drake's pond, near Newton	......	1.27		*a*52.85	*b*.76	.....	3.19	......
502	"	Franklin	......	.5		*a*53.53	*b*1.73	43.97	.55	......
503	"	Hamburg............	15.7	6		42.28	33.26	1.35	....	......
504	"	Hardystonville	......	.15		*a*51.8	*b*1.37	42.23	1.7	1.8
505	"	Hamburg	7.02	5 43		47.4	37.19	*c*1.17	....	.....
506	"	Hunts Mill..........	......	....	....	96.32	1.57	.....	1.16	.96
507	"	Iliff's pond	.....	1.82		*a*54.04	*b*.81	.....	2.87	......
508	"	"	9.5	1.42		*a*47.95	*b*.57	.....	3.55	......
509	"	Jenny Jump mountain	......	1		*a*42.45	*b*10.23	44.67	1.91	......
510	"	Lafayette	....	1.81		*a*49.11	*b*.65	....	9.53	......
511	"	N. W. of Lafayette.	....	.61		*a*39.12	*b*8.21	......	13.52	......
512	"	N. of Lafayette.....	10.72	1.46		*a*49.13	*b*.34	....	2.69	......
513	"	N. J. bank, Milford ferry	.....	1.8		*a*47.34	*b*1.24	38.9	10.3	......
514	"	Monroe Corners	......	....	....	94.75	....	......	.71	4.54
515	"	"	....	1.49		*a*49.03	*b*.7	......	10.67	.....
516	"	3 m. s. w. of Monroe	......	1.63		*a*43.09	*b*.73	.....	26.51	......
517	"	Montague	8.7	1.5		*a*49.67	*b*.69	40	....	......
518	"	"	.43	.45		*a*50.27	*b*.62	38.57	....	&org. 6.07
519	"	"	.37	.16		*a*50.38	*b*.36	38.9	....	&org. 4.83
520	"	"	1.21	2.12	1.28	*a*9.71	*b*.42	7.25	66.57	&org. 7.6
521	"	"	1.15	2.49		*a*8.45	*b*.43	6.12	66 97	&org. 10 46
522	"	Newton[1]............	......	.6		*a*29.4	*b*20.3	45.7	1.8	......
523	"	"	......	.9		*a*28.6	*b*18.1	34.5	9.3	......
524	"	"	......	.9		*a*29	*b*20.2	44.9	4.8	......
525	"	"	......	4 7		*a*49	*b*.9	39.4	5.8	.....
526	"	"	......	....	....	96.54	1 47	.....	2.05	......
527	"	"	......	....	....	84.52	1.76	......	8.46	&org. 5.26
528	"	"	......	1.9		*a*28.22	*b*19.07	....	8.13	......
529	"	3 m. s. w. of Newton.	......	1.6		*a*46.88	*b* .4	......	11.96	.....
530	"	4 m. n. e. "	......	2.44		*a*41.12	*b* 3.78	.....	17.23	.....

[1] See also analyses 460, 461, 462 and 471

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
494	....	N. J. geol. sur. 1868, p. 399	Blue limestone. Nearpass quarry
495	K_2O 1.34 P_2O_5 .25	" " "	Cement layer. Nearpass quarry
496	....	" " "	Quarry stone. Nearpass quarry
497	....	" " "	Best stone. Nearpass quarry
498	....	" 1877, p. 24	F. Layton's farm
499	Alkalis .5	" 1868, p. 395	
500	....	" " p. 480	Travertine
501	....	" 1900, p. 78	J. Ayres' farm
502	....	" 1871, p. 44	White crystalline limestone
503	....	" 1873, p. 108	Quarry of R. Howell
504	....	" 1868, p. 404	G. W. Rude. White limestone
505	....	" 1873, p. 108	R. Howell's farm
506	....	" 1877, p. 24	D. M. Howell. Marl
507	....	" 1900, p. 79	Trenton limestone
508	....	" " "	"
509	....	" 1868, p. 402	White limestone. East side of mountain
510	....	" 1900, p. 74	Z. Simmons' farm
511	....	" " p. 75	Trenton limestone
512	....	" " p. 74	J. C. Demorest
513	....	" 1868, p. 399	Corniferous
514	....	" 1877, p. 24	Marl. White Pond
515	....	" 1900, p. 73	Trenton limestone
516	....	" " "	"
517	....	" 1868, p. 399	Lower Helderberg. J. Cole's farm
518	....	" " p. 479	Surface. I. Bonnell farm, Chamber's Mill brook
519	....	" " "	Same 10 ft below surface
520	....	" " "	Dark gray marl. 8 ft below surface. J. Cole
521	....	" " "	Marl. I. Van Etten, 4 ft below surface
522	....	" " p. 395	Moore & Cutler quarry
523	....	" " "	"
524	....	" " "	"
525	....	" " p. 398	W. T. Babbitt's farm
526	....	" 1877, p. 24	M. Drake's farm. Marl
527	....	" " "	
528	....	" 1900, p. 33	O'Donnell & McManniman quarry
529	....	" " p. 80	Whittingham estate
530	....	" " p. 76	

*a*CaO *b*MgO L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	N. Jersey (c'd)									
531	Sussex	4 m. n. e. of Newton	......	1.04		a37.95	b11.68	......	8.48	......
532	"	"	......	2.37		a30.46	b 9.82	......	24.91	......
533	"	Myrtle Grove	......	1.09		a48.36	b .56	......	11.86	......
534	"	Huntsburg	......	1.94		a50 16	b 1.67	......	5.5	......
535	"	"	..	1.41		a47.55	b .65	......	14.85	......
536	"	Ogdensburg	.5	3.5		a29.68	b20.07	45 51	....	......
537	"	Peters valley	9.8	2.1		a48.88	b .35	38.9	....	......
538	"	"	.38	.8		a43.68	b .14	34.44	19.39	.36
539	"	Roseville	......	......	1.5	a53.31	b 1.7	43.78	....	......
540	"	Sparta	9.5	1.2		a28.31	b18.04	42.08	....	......
541	"	"	......	1.7		a28.5	b17.3	41.5	9.9	.3
542	"	"	......	.8		a51.06	b 3.02	43.44	1.4	......
543	"	Springdale	......	.8		a49.4	b 1	40.1	6.6	......
544	"	"	......	.81		a54.26	b 1.09	......	1.7	......
545	"	"	......	1.19		a50.65	b .55	40 41	7.83	......
546	"	Stillwater	......	.2		a54.7	......	43	1.8	......
547	"	"	......	1.6		a43.2	b 2.2	31.4	15.8	......
548	"	Swartswood	......	4.37		a24.89	b 3.74	......	43.38	......
549	"	Sussex lead mine	......	1		a51.07	b 3.02	47.47	.3	......
550	"	Vernon township	......	.5	.3	a30.4	b19.1	44 9	3.6	.3
551	"	Cranberry reservoir	......	.7		a53.93	b 1.25	43.76	1	......
552	"	Vernon township	......	.9		a4.84	b 5.25	43.8	.27	.2
553	"	"	......	.9		a54.79	......	43.06	.75	.15
554	"	Walpack Center	......	2.1		a44.85	b 2.18	37.68	12.8	......
555	"	" Ridge	......	2.6		a45.19	b .8	36.75	10.8	......
556	"	Wantage township	......	2.2	.5	a30	b19.4	44.9	2.3	.5
557	"	"	......	1.3	.9	a29.3	b19.5	44.6	4	.3
558	"	"	......	.7	.5	a29.1	b19.3	43.4	6.4	.3
559	"	"	......	.3	.6	a27.9	b17.7	41.4	11.2	.3
560	"	"	......	.4	.2	a30.3	b16.2	41.6	9.8	.7
561	"	West Vernon	......	.2		a51.96	b 2.92	44.03	.2	......
562	"	Wynokie	......	5.3		a29.01	b10.8	23	29.3	2
563	Warren	Asbury	.....	.8		a29.4	b17.8	42.8	8.8	......
564	"	Belvidere	1.86	.6	.51	a53.64	b .81	43.03	....	......
565	"	"	2.52	.44	.47	a53.24	b 1.08	42.62	....	......
566	"	"	2.03	.57	.51	a53.02	b .91	42.69	....	......
567	"	"	5 03	2.06	1.83	a49.73	b 1.02	40.19	....	......

a CaO b MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
531	....	N. J. geol. sur. 1900, p. 76........................	Trenton limestone
532	....	" " "	
533	....	" " p. 55	¾ mile s. w. Myrtle Grove
534	....	" " p. 81........................	North of Huntsburg school-house
535	....	" " "	North of Huntsburg school-house
536	....	Geol. of N. J. 1868, p. 404........................	Tunnel n. e. of Sterling Hill
537	....	" " p. 399........................	J. Schooley farm
538	....	" " p. 479	Tufa. B. P. Van Syckle farm
539	....	" " p. 402........................	O. Himenover farm
540	....	" " p. 403........................	Crystalline limestone, J. B. Titman farm
541	....	" " p. 394........................	Blue limestone, J. B. Titman farm
542	....	N. J. geol. sur. 1871, p. 44........................	Crystalline limestone, J. B. Titman farm
543	....	Geol. of N. J. 1868, p. 398........................	D. Farrell farm
544	....	N. J. geol. sur. 1900, p. 82........................	J. Wolf farm
545	....	" " p. 83........................	J. Farrell farm
546	Alkalis .4	Geol. of N. J. 1868, p. 398........................	W. A. Mains quarry
547	....	" " "	A. T. Mains quarry
548	....	N. J. geol. sur. 1900, p. 56	⅛ mile west of railroad
549	....	Geol. of N. J. 1868, p. 403........................	Crystalline limestone
550	Alkalis 1.5 P_2O_5 .2	" " p. 395........................	¼ mile n. w. of W. Richey house
551	....	" " p. 402........................	Musconetcong iron co. quarry
552	Alkalis .5	" " p. 404........................	P. J. Brown quarry
553	Alkalis .16	" " "	"
554	....	" " p. 398........................	R. Stoll farm
555	....	" " p. 399........................	C. Decker farm
556	Alkalis .1	" " p. 395........................	300 yds. from D. Perry house
557	" .3	" " "	¼ mile n. w. of S. Vanderhoof
558	" .3	" " "	300 yd. west of W. Dewitt
559	" .3	" " "	Near house of E. Lewis
560	" .2	" " "	"
561	....	N. J. geol. sur. 1871, p. 44........................	Crystalline limestone
562	Alkalis .21	Geol. of N. J. 1868, p. 401........................	"
563	....	" " p. 394........................	M. Fox quarry, *see* p. 933
564	....	N. J. geol. sur. 1900, p. 95........................	Series of analyses made from samples taken chiefly on Morris & Earye farms near Belvidere. Analyses are all of the Trenton beds, which in this area furnish Portland cement rock
565	....	" " "	
566	....	" " "	
567	....	" " "	

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	N. Jersey (*c'd*)									
568	Warren........	Belvidere...........	5.37	3.45	.98	*a*49.5	*b*.85	39.84	....	......
569	"	"	5.76	3.25	1.36	*a*49.3	*b*.64	39.44	....	......
570	"	"	5	2.84	1.28	*a*48.72	*b*.96	39.33	....	......
571	"	"	8.38	4.03	1.32	*a*45.45	*b*1.34	37.18	....	......
572	"	"	11.9	4.42	1.7	*a*44.18	*b*1.18	36 01	....	......
573	"	"	11.71	4.33	1.62	*a*43.47	*b*1.82	36.15	....	......
574	"	"	12.46	4.82	1.62	*a*43.44	*b*1.15	35.41	....	......
575	"	"	12.8	5.39	1.7	*a*42.85	*b*1.35	35.16	....	......
576	"	"	11.11	4 4	1.91	*a*42.51	*b*2.89	36.57	....	......
577	"	"	13 82	5.03	1.7	*a*42.3	*b*1.49	34.86	....	......
578	"	"	14.54	5.59	1.83	*a*41.19	*b*1.46	34 08	....	......
579	"	"	20.59	5.33	1 87	*a*38.38	*b*1.39	31.67	....	......
580	"	"	14.9	7.42	1.87	*a*38.2	*b*1.09	31.2	....	......
581	"	"	17.04	6.9	2 13	*a*37.53	*b*2.17	32.88	....	......
582	"	"	22 71	5.84	2.13	*a*36.5	*b*1.69	30.52	....	......
583	"	"	22.39	6.9	1.74	*a*36.41	*b*1.53	30 3	....	......
584	"	"	16.2	6.71	1.91	*a*36.37	*b*3.21	32.1	....	......
585	"	"	19.53	6.03	1.7	*a*35.71	*b*3.33	32.73	....	......
586	"	"	22.77	6.53	2.52	*a*35.05	*b*1.52	29.2	....	......
587	"	"	22.96	7.35	2.04	*a*35.03	*b*1.59	29.28	....	......
588	"	"	24.45	5.68	1.57	*a*35	*b*2.21	29.89	....	......
589	"	"	27.9	7.89	1.7	*a*32.1	*b*1.4	26.78	....	......
590	"	"	22.72	8.15		*a*35.78	*b*1.86	....	....	......
591	"	"	......	1.4		*a*29.6	*b*19.2	46.2	2.9	......
592	"	"	......	1		*a*53.4	*b*.4	42.6	2.7	......
593	"	S. of Branchville....	......	.46		*a*54.98	*b*.84	......	2.27	......
594	"	Budgeville station..	27.08	8.76		55.37	3.83	....	....	2.6
595	"	Bushkill.............	......	1.3		*a*29.8	*b*19.3	44.7	4.3	......
596	"	Carpentersville	17.707	7.915		*a*41.794	*b*.38	33.25	....	......
597	"	"	14.595	6.861		*a*40.296	*b*.671	32 5	....	......
598	"	"	10.712	5.982		*a*39.999	*b*.654	32.15	....	......
599	"	"	10.262	7.186		*a*44.722	*b*1.401	36.68	....	......
600	"	"	20.578	5.441		*a*39.839	*b*.629	32	....	......
601	"	⅛ m. s. e. of Columbia	......	1.23		*a*52.58	*b*.65	......	4.3	......
602	"	Columbia	......	1.4		*a*29.6	*b*20	45.4	2.3	......
603	"	Hainesburg	(2.62)	2.38		*a*48.04	*b*2.84	......	5.48	......
604	"	Hope................	......	....	....	89.87	2.29	......	.97	......

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
568		N. J. geol. sur. 1900, p. 95	
569		" " "	
570		" " "	
571		" " "	
572		" " "	
573		" " "	
574		" " "	
575		" " "	
576		" " "	
577		" " "	Series of analyses made from samples taken chiefly on Morris & Earye farms near Belvidere. Analyses are all of the Trenton beds, which in this area furnish Portland cement rock
578		" " "	
579		" " "	
580		" " "	
581		" " "	
582		" " "	
583		" " "	
584		" " "	
585		" " "	
586		" " "	
587		" " "	
588		" " "	
589		" " "	
590		" " p. 94	Railroad cut
591		Geol. of N. J. 1868, p. 394	
592		" " p. 398	Fossiliferous limestone
593		N. J. geol. sur. 1900, p. 53	Trenton limestone
594	Undet. 2.36	" " p. 92	Iliff property
595		Geol. of N. J. 1868, p. 396	Wagner quarry, one mile from Easton
596		N. J. geol. sur. 1900, p. 42	Murphy farm
597		" " "	"
598		" " "	"
599		" " "	"
600		" " "	"
601		" " p. 66	Trenton limestone
602		Geol. of N. J. 1868, p. 395	First outcrop east of Van Kirk's tavern
603		N. J. geol. sur. 1900, p. 66	Trenton limestone
604	Org. and water 6.87	" 1877, p. 24	H. S. Cook. Marl

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	N. Jersey (*c'd*)									
605	Warren	Jacksonburg	......	3.57		*a*2.41	*b*1.46	......	87.2	......
606	"	"	......	.86		*a*55.7	*b*.45	......	.97	......
607	"	Lincoln	......	....	....	90.18	....	......	9 75	......
608	"	Marksboro	......	....	....	92.25	2.98	......	1.56	......
609	"	New Hampton	......	1		*a*29.8	*b*19.9	45 4	3.4	......
610	"	Oxford	......	1.3		54.04	.53	43.06	.9	......
611	"	" Furnace	......	.33	.97	*a*50.3	42.4	......	5.5	......
612	"	Phillipsburg	......	1.1		*a*30.8	*b*19 2	45.4	3.6	......
613	"	Sarepta	......	1		*a*47.37	*b*2.06	....	2.92	......
614	"	"	5.46	.81	1.02	*a*49.38	*b*2.26	......	....	......
615	"	Shiloh	....	....	....	97.73	....	......	.6	......
616	"	Springtown	......	1.8	.6	29.2	18.8	43.6	3.6	.6
617	"	Stewartsville	23.04	8.15	2.41	*a*33.7	*b*.83	27.4	....	......
618	"	"	19.32	7	1.99	*a*36.86	*b*1.06	30.14	....	......
619	"	"	19.51	7.05	2.03	*a*36.8	*b*1.18	30.2	....	......
620	"	"	23.68	8.12	2.57	*a*33.3	*b*1.41	27.57	....	......
621	"	"	20.29	6.85	2.11	*a*36.84	*b*1.34	30.29	....	......
622	"	"	19.98	7.23	1.99	*a*36.78	*b*.58	29.54	....	......
623	"	"	21.1	7.68	1.92	*a*35.45	*b*.48	28.38	....	......
624	"	"	18.15	6.08	1.78	*a*38	*b*1.63	31 65	....	......
625	"	"	21.32	8.16	2.22	*a*35.19	undet.	27.56	....	......
626	"	"	21.72	8.27	2.34	*a*35.3	"	27.73	....	......
627	"	"	33.9	11.94		*a*27	"	21.21	....	......
628	"	"	35.95	11.28		*a*25.71	"	20 2	....	......
629	"	"	31.39	10.48		*a*38.84	"	22.66	....	......
630	"	"	17.97	8.27		*a*37.87	"	29.76	....	......
631	"	"	24.91	8.4		*a*34.44	"	27.02	....	......
632	"	"	35.07	11.6		*a*25 64	"	20.14	....	......
633	"	"	19.17	6.23	2.57	*a*37.51	"	29.47	....	......
634	"	"	20.2	5.92	2.53	*a*37.51	"	29.47	....	......
635	"	"	16.97	6.03	2.26	*a*38.29	"	30.09	....	......
636	"	"	19 87	7.83	3 95	*a*35.61	"	37.94	....	......
637	"	"	16.81	9.76		*a*38.81	"	..	....	......
638	"	"	17.96	7.11	2.53	*a*37.95	"	29.82	....	.....
639	"	Swayze's Mills	......	.82		*a*53.88	*a*.72	......	2.64	....
	New York									
640	Albany	South Bethlehem...	9.05	6.66	.99	79.86	4.17	......	....	.....

a CaO *b* MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
605	....	N. J. geol. sur. 1900, p. 63........................	Weathered sandy limestone
606	....	" " "	Pure limestone, same ledge as preceding
607	....	" 1877, p. 24.	Sink pond. Marl
608	Org.and water 3.21	" " "	White pond. Marl
609	....	Geol. of N. J. 1868, p. 394........................	J. Riddle quarry
610	....	" " p. 402........................	P. Raub quarry. White crystalline limestone
611	....	N. J. geol. sur. 1876, p. 55	Blue limestone
612	....	Geol. of N. J. 1868, p. 394	C. Twining's quarry
613	....	N. J. geol. sur. 1900, p. 94.	Trenton limestone
614	....	" " "	"
615	Org.and water 1.59	" 1877, p. 24........................	A. M. Cooke
616	Alkalis 8 P_2O_5 .2	Geol. of N. J. 1868, p. 394	R. Shimer quarry
617	....	N. J. geol. sur. 1900, p. 45	Trenton limestone from quarry of Edison Portland cement co., one mile n. e. of Stewartsville
618	....	" " "	
619	....	" " "	
620	....	" " "	
621	....	" " "	
622	....	" " "	
623	....	" " "	
624	....	" " "	
625	....	" " "	
626	....	" " "	
627	....	" " "	
628	....	" " "	
629	....	" " "	
630	....	" " "	
631	....	" " "	
632	....	" " "	
633	....	" " p. 46	
634	....	" " "	
635	....	" " "	
636	....	" " "	
637	....	" " "	
638	....	" " "	
639	....	" " p. 89	Trenton limestone
640	....	N. Y. state geol. rep't 1897, p. 430........................	Lower third of Callanan quarry

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	New York (*c'd*)									
641	Albany.........	South Bethlehem..	5.12	1.45	.74	*a*48.34	*b*2.93	41.22	....	......
642	"	" ...	11.16	3.35	1.15	79.06	6.65	......	....	.....
643	Clinton.........	Chazy..............	.72	.39		96.24	3.02	......	....	......
644	"	"	.79	.14	.12	97 08	1 4	.....	....	......
645	Columbia.......	Hudson.............	1.84	.635	1.82	*a*51.4	*b*2.23	41.19	....	......
646	"	"	1.89	1.01	.55	91.7	3.51	......	....	......
647	Dutchess........	Clinton Point........	10.17	2.33	.47	*a*29.07	*b*16.29	40.76	....	......
648	"	South Dover	.71	.37	.25	*a*30.63	*b*20.25	......	....	......
649	Erie...........	Williamsville........	.17	.84		96.54	1	......	....	......
650	Essex..........	Willsboro Point.....	2.43	....		*a*51	*b*1	......	....	......
651	Greene.........	Catskill..............	2 75	1.5	1.6	*a*53.1	......	42.1	....	......
652	"	Sm'ths Landing ...	1.54	.39	1.04	*a*53.87	*b*.52	......	....	......
653	Herkimer.......	Little Falls..........	10.5	8.03	.77	47.96	36.89	...	....	......
654	"	Columbia............	4.01	.48	.53	*a*51.82	*b*1.16	41 9	....	......
655	"	Ingham Mills........	6.7	3.03	.21	89.15	trace	......	....	......
656	"	"	8.45	2.72	.84	84.6	3.42	......	....	......
657	Lewis..........	Port Leyden.........	6.5	1.67	.76	88.44	2.68	......	....	......
658	"	Leyden.............	1.44	.83		97.36	1.04	......	....	......
659	"	Collinsville..........	3.09	1.15	.49	94.11	1.63	......	....	......
660	"	Lowville.............	3.96	1.7		91.27	3.78	......	....	......
661	Monroe.........	Brighton............	1.12	.27	.39	*a*29.38	*b*22.1	47.39	....	......
662	"	Gates	.7	.95	.8	*a*30.5	*b*20.05	45.24	....	......
663	"	Rochester...........	.29	.43	.46	56.01	43.3	......	....	......
664	Montgomery...	Amsterdam..........	1 25	3		*a*52.78	......	42.97	....	......
665	" ...	"	3 82	1.08		*a*52.46	......	42.64	....	......
666	" ...	"	5.68	2.76		*a*52.12	......	39.44	....	......
667	" ...	"	6.13	.79	.61	88.49	2.45	......	....	......
668	" ...	"	7.46	2.48	1.07	71.76	18.19	......	....	......
669	Niagara........	Lockport..	7.09	2.57	.96	56.19	33 42	......	....	......
670	"	Niagara Falls......	1.7	1.3	.75	*a*42.21	*b*17.45	37.5	....	......
671	Oneida.........	Prospect.......	2.59	1.21	.61	*a*52	*b*1.04	42	....	......
672	"	Near Clinton........	7.23	1.64		*a*48.68	*b*1.84	40.29	....	......
673	"	"	1.92	.36		*a*52.53	*b*.69	42.03	....	......
674	"	"	......	....		*a*35.25	*b*8.94	37.52	....	......
675	"	"	5.53	1.5		*a*50.25	*b*1	40 49	....	......
676	"	Oriskany Falls	5.56	1.55		*a*50.47	*b*.83	40.57	....	......
677	"	"	2.57	1.55		*a*52.69	*b*.84	42 33	....	......

a CaO *b* MgO

THE UNITED STATES *(continued)*

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
641	....	N. Y. state geol. rep't 1897, p. 430.................	Middle third of Callanan quarry
642	....	" " p. 431.................	Upper third of Callanan quarry
643	....	" " p. 433; D. H. Newland. anal.	Chazy limestone
644	....	N. Y. state geol. rep't 1897, p. 433.................	
645	....	" " p. 431; T. Eggleston, anal.	Jones quarry
646	....	N. Y. state geol. rep't 1897, p. 431.................	"
647	....	" " "	
648	Alkalis .58	" " "	South Dover marble co. quarry
649	S .101	" " p. 436; H. Carlson, anal.	Fogelsonger & Young quarry
650	....	" " p. 437; J.F. Kemp, anal.	Partial analysis
651	....	" " " "	Holdredge's quarry
652	....	Engineering news. 45:365............................	Catskill cement co. quarry
653	....	N. Y. state geol. rep't 1897, p. 438.................	
654	....	" " "	Tentaculite limestone
655	....	" " p. 439.................	Birdseye, Butler quarry, lower massive layer
656	....	" " "	Birdseye, average of quarry
657	....	" " " D. H. Newland, anal.	Trenton limestone. P. Snyder farm
658	....	N. Y. state geol. rep't 1897, p. 440.................	Christy quarry
659	....	" " " D. H. Newland, anal.	Roberts quarry
660	....	N. Y. state geol. rep't 1897, p. 441.................	J. Waters quarry
661	....	" " "	Rochester lime co. quarry
662	....	" " p. 442; D. H. Newland, anal.	Snow quarry
663	....	N. Y. state geol. rep't 1897, p. 442; D. H. Newland, anal.	Copeland quarry
664	....	N. Y. state geol. rep't 1897, p. 443; Sherrerd, anal.	D. C. Hewitt quarry, upper layer
665	....	" " " "	D. C. Hewitt quarry, intermediate
666	....	" " " "	D. C. Hewitt quarry, lower
667	....	" " "	D. C. Hewitt quarry
668	....	" " p. 444.................	G. Ross quarry
669	....	" " p. 445; D. H. Newland, anal.	Quarry 2 miles e. of town
670	....	N. Y. state geol. rep't 1897, p. 445; H. Ries, anal...	W. Messing quarry
671	....	" " " p. 446; J. D. Irving, anal.	Trenton limestone
672	S .21	N. Y. state geol. rep't 1897, p. 446; A. H. Chester, anal.	
673	....	N. Y. state geol. rep't 1897, p. 446; A. H. Chester, anal.	
674	....	N. Y. state geol. rep't 1897, p. 446; A. H. Chester anal.	
675	S .3	N. Y. state geol. rep't 1897, p. 446; A. H. Chester, anal.	
676	S .21	N. Y. state geol. rep't 1897, p. 446; A. H. Chester, anal.	
677	SO_3 .14	N. Y. state geol. rep't 1897, p. 446; A. H. Chester. anal.	

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	New York (c'd)									
678	Oneida	Oriskany Falls	5.66	2.14		a50.25	b1.11	40.7	....	......
679	"	"	5.46	1.35		a50.8	b1.01	41.02	....	......
680	"	"	5.82	1.38		a50.93	b.85	40.87	....	......
681	Onondaga	Jamesville L	......	2.03		a91.93	b3.06	......	1.88	1.47
682	"	Manlius	20.3	13.67		a47.48	b18.55	......	....	......
683	"	Jamesville L	10.97	4.46	1.54	a27.51	b16.9	37.94	....	......
684	"	"	10.95	5 32	1.3	a30.92	b13.64	38 31	....	......
685	"	Split Rock	5.35	.56	.61	85 41	18.86	......	....	......
686	Orange	Newburg	10.46	1.95	1.8	a27.75	b17.65	40.46	....	......
687	Rockland	Tomkins Cove	12	4.13	1.05	a26.34	b16.74	39.1	....	......
688	Rensselaer	Hoosick Falls	1.2	2	1.5	a34.11	b8.97	......	....	......
689	Saratoga	Sandy Hill	......	.46	1.02	a29.05	b2.8	38.6	18.04	......
690	St Lawrence ...	Ogdensburg	4.42	2.23	.16	55.87	37.74	......	....	......
691	" ...	"	17.28	5.21	.92	58.17	18.46	......	....	......
692	" ...	Between Colton and Canton	.5	1.3		88.67	9.53	......	....	......
693	" ...	1 m. from Canton ...	1.12	1.89		76.48	19.97	......	....	......
694	" ...	Gouverneur	1.85	.23	.38	92.29	4.28	......	....	......
695	Schoharie	Howe Cave	1.27	.73		97.24	1.39	......	....	......
696	"	Cobleskill	4.31	.97		a51.05	b1.65	47.14	....	......
697	Ulster	Rondout	3.87	1.07	1.34	a54.11	b trace	40.6	....	......
698	"	Wilbur	7.1	2.5	1.65	a45.22	b trace	39.1	....	......
699	Warren	Glens Falls	3.9	1.3	......	a52.15	b1.58	......	....	......
700	"	"	1.1	.8	.5	a53.17	b.75	42.8	....	......
701	Washington	Smith's Basin	1.38	.58		a55.26	b.72	......	....	......
702	" L	"	......	.58		a95.5	b trace	......	1.06	&CO_2 2.08
703	"	"	.72	1.5		54.28	.8	43.1	....	......
704	Westchester ...	Annsville Cove	2.5	1.55		81.64	13.5	......	....	......
705	"	Ossining	.87	.57	.25	a31.4	b19.95	......	....	......
706	"	"	5.12	.75		a25.42	b22.35	......	....	......
707	"	"	6.77	1.81		a45.02	b13.16	......	....	......
708	"	"	5.94	2.82		a29.05	b20.05	......	....	......
709	"	Pleasantville	2.31	.4	.25	59.84	36.8	....	....	......
710	"	Tuckahoe	.24	.19	.21	a30.16	b21.25	47.3	....	.02
	Ohio									
711	Allen	Lima	......	....	....	a32.24	b17.36	43.92	1.64	......
712	Auglaize	St Mary's township.	......	3.12		52.18	38.42	......	3.18	......
713	"	"	......	2.48		56.94	35.55	......	1.66	......

aCaO bMgO

THE UNITED STATES *(continued)*

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
678	S .18	N Y. state geol. rep't 1897, p. 446; A. H. Chester, anal.	
679	S .12	N. Y. state geol. rep't 1897, p. 446	
680	S .07	" " "	
681	SO_3 .73	" " p. 449; Englehardt, anal.	E. B. Alvord & Co.
682	....	....	Brown cement co. Cement
683	....	N. Y. state geol. rep't 1897, p. 449	Upper cement layer. Alvord quarry
684	....	" " "	Lower cement layer. Alvord quarry
685	....	" " "	Solvay process co. quarry
686	....	" " p. 451; J. D. Irving, anal.	Miller quarry
687	....	N. Y. state geol. rep't 1897, p. 450	
688	....	" " p. 452	McCaffery quarry
689	....	" " p. 453	Higley, Monty & Co. quarry
690	....	" " "	Upper stone, Howard quarry
691	....	" " p. 454	Lower stone, Howard quarry
692	....	" " " Prof. Priestly, anal.	
693	....	N Y. state geol. rep't 1897, p. 454; Prof. Priestly, anal.	Stevens quarry
694	....	N. Y. state geol. rep't 1897, p. 455; J. D. Irving, anal.	
695	....	Eng. News, 45, p. 365; C. A. Schaeffer, anal.	Helderberg cement co. quarry
696	....	....	Cobleskill quarry
697	....	N. Y. state geol. rep't 1897, p. 457	Newark lime & cement co. quarry
698	....	" " "	B. Turner quarry
699	SO_3 .3	" " p. 459	Top-stone
700	....	" " p. 460	Lower stone
701	....	" " p. 461	Keenan lime co. quarry
702	....	" " "	
703	....	" " "	Keenan lime company
704	....	" " p. 466; J. D. Irving, anal.	2 miles west of Peekskill
705	....	N. Y. state geol. rep't 1897, p. 463	Sing Sing lime co. quarry
706	....	" " "	Mark's quarry
707	P_2O_3 .027	" " "	"
708	....	" " "	"
709	....	" " p. 466	Cornell quarry
710	....	" " p. 465	O'Connell & Hillery
711	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke and R. B. Riggs, anal.	Oil rock
712	....	U. S. geol. sur. Bul. 148, p. 262; C. Catlett, anal. ..	Gas rock, Pauck well
713	....	" " " ..	Bennett well

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Ohio (*cont'd*)									
714	Clark........ ...	Cold Springs.........	......	.23		54.05	44.94	......	.49	......
715	"	New Carlisle.......	......	.29		96.8	2.07	......	.83	......
716	"	Springfield..........	......	.56		54.13	44.37	......	.65	......
717	"	"	......	.39		53.88	43.79	......	1.55	......
718	Clermont	Point Pleasant......	......	7		79.3	.91	......	12	......
719	Clinton	New Vienna	......	......	....	*a*47.16	*b*1.52	36.2	8 47	......
720	"	"	......	....	....	*a*49.04	*b*.58	37.64	9.93	.....
721	"	"	......	....	....	*a*51.18	*b*3.08	42.04	2.12	......
722	"	"	......	....	....	*a*23	*b*12.9	30.82	28.43	......
723	Columbiana ...	New Lisbon.........	9.01	3.38		85.55	2.82	....	....	......
724	"	"	12.63	5.04	2.43	75 51	3 86	......	....	.7
725	"	"	33.93	14.3	4.29	35.56	6 09	......	....	5.2
726	" ...	"	36.69	15.17	4.82	27.22	7.83	......	....	7.6
727	Darke	New Madison	......	3.6		64.91	17.98	......	11.11	......
728	"	"	......	....	....	51.7	45 26	.....	2.7	......
729	"	Greenville	......	....	....	44.69	50.11	.....	4.6	......
730	Erie	Sandusky	......	.35		89.08	8.34	......	1.51	......
731	"	"	......	4.58		54.62	33.67	......	3.65	......
732	Franklin	Columbus...........	.....	.8		94.8	1.21	......	3.2	......
733	"	"	......	1.74		93.21	4.7	......	....	......
734	Fulton	Wauseon	......	7.28		42.82	28.11	......	18.24	.....
735	Greene	Cedarville	......	.53		53.9	44.58	.....	.88	......
736	"	Osborne	......	.36		97.09	.82	......	1.64	......
737	"	Yellow Springs	......	1.4		51.1	41.12	......	5.4	......
738	"	Xenia	......	.18		86.54	2.99	......	9.23	......
739	Hancock	Arcadia	.....	....	....	*a*47.17	*b*2.59	38.54	8.56	......
740	....	Findlay	1.55	.39		53.88	43.79	......	....	......
741	Hardin	Kenton	......	1.1		84.32	8.43	......	5.26	......
742	Highland	Greenfield	1	1.3		53.67	42.42	......	1.44	......
743	"	"	1.45	1		49 9	44.87	......	2.98	......
744	"	Lexington	1.6	2.2		54.1	41.77	......	....	......
745	"	Leesburg	.69	.9		49.76	45.77	......	2.88	......
746	"	Napoleon	....	2.14		53.85	37.33	.....	2.66	......
747	Logan	Huntsville	......	3.15		57.23	33.16	......	4.41	......
748	Lucas	Toledo	......	8.68		54.68	25.73	......	2.88	......
749	Madison	London	.....	1.84		77.69	1.89	.....	15.9	......
750	Marion	Marion	......	2.3		86.22	9.27	......	2.86	......

*a*CaO *b*MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
714	....	U. S. geol sur. 20th rep't, pt 6 cont'd, p. 432; E. Lovejoy, anal.	Casparis stone co.
715	....	Ohio geol. sur. Ec. geol 6:728; N. W. Lord, anal...	Brown quarries
716	....	" " 6:716 " ...	Pettigrew
717	....	" " 6:717 " ...	G. H. Frey quarry
718	....	Merrill. Stones for building and decoration, p. 467	
719	....	U. S. geol. sur. Bul. 148, p. 260; F. W. Clarke and R. B. Riggs, anal.	
720	....	U. S. geol. sur. Bul. 148, p. 260; F. W. Clarke and R. B. Riggs, anal.	
721	....	U. S. geol. sur. Bul. 148, p. 260; F. W. Clarke and R. B. Riggs, anal.	
722	....	U. S. geol. sur. Bul. 148, p. 260; F. W. Clarke and R. B. Riggs, anal.	
723	....	Ohio geol. sur. 5:1109; N. W. Lord, anal............	White limestone
724	....	" " "	First limestone below white, top stratum
725	....	" " "	First limestone below white, middle stratum
726	....	" " "	First limestone below white, lower stratum
727	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke, anal.	Trenton limestone
728	....	Ohio geol. sur. Ec. geol. 6:726; Wormley, anal.....	Northrop quarry
729	....	" " " "	Bierly quarry
730	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432.......	Olemacher lime co.
731	....	" Bul. 148, p. 262; C. Catlett, anal....	Trenton limestone
732	....	" 20th rep't, pt 6 cont'd, p. 432.......	T. J. Price & Co.
733	....	" " " "	Casparis stone co.
734	....	" Bul. 148, p. 262; C. Catlett, anal....	
735	....	Ohio geol. sur. Ec. geol. 6:720; N. W. Lord, anal...	Ervin quarry
736	....	" " 6:728 " ...	G. Haddock quarry
737	....	Merrill. Stones for building and decoration, p. 468.	
738	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke, anal.	Trenton limestone
739	....	" " F. W. Clarke and R. B. Riggs, anal.	"
740	....	Ohio geol. sur. Ec. geol. 6:744; N. W. Lord, anal...	Barnd quarry
741	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke, anal.	McElree well
742	....	Ohio geol. sur. Ec. geol. 6:730; Wormley, anal.....	Rucker quarry
743	....	" " " "	Wright quarry
744	....	" " " "	"
745	....	" " " "	Pope quarry
746	....	U. S. geol. sur. Bul. 148, p. 262; C. Catlett, anal....	Trenton limestone
747	....	" " p. 261; F. W. Clarke, anal.	"
748	....	" " p. 262; C. Catlett, anal....	Air Line Junc.; depth 1415 ft
749	....	" " " " ...	Depth 1594 ft
750	P_2 .11	" 20th rep't, pt 6 cont'd, p. 432.......	Norris & Christian lime & stone co.

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Ohio (*cont'd*)									
751	Marion	Prospect	......	2.57		66.02	3.77	......	26.12	......
752	Mercer	Celina	......	2.95		68.41	24.18	......	2.95	......
753	"	Fort Recovery	......	1.57		87.88	7.43	......	1.89	......
754	"	Franklin township	......	8.38		69.53	10.98	......	3.68	......
755	"	St Henry	......	....	....	*a*50.34	*b*2.86	40.96	2.27	......
756	Miami	Covington	3.77	.33	.67	53	37.11	......	....	......
757	"	Rex	......	.4		95.6	3.93	......	.07	......
758	Montgomery	Dayton	......	.58		82.36	1.67	......	12.34	......
759	Ottawa	Genoa	......	.16		54.3	45.14	......	.23	......
760	"	Port Clinton	......	4.16		71.96	14.34	......	7.46	......
761	"	Genoa	......	.23		55.97	44.27	......	.04	......
762	"	"	......	.51		53.04	46.01	......	.22	......
763	"	"	......	.16		54.3	45.14	......	.23	......
764	"	"	......	.42		55.59	43.67	......	.28	......
765	"	"	......	.44		54.61	45.05	......	.24	......
766	"	Rocky Ridge	......	.29		54.1	44.27	......	.87	......
767	"	Williston	.21	.21		53.9	44.82	......	....	......
768	Perry	Monday creek township	3.76	7.16		57.86	30.78	......	....	.1
769	Preble	New Paris	......	.37		61.33	37.68	......	.61	......
770	Sandusky	6 m. w. of Fremont	......	6.32		52.93	32.75	......	5.22	......
771	"	Woodworth	......	.39		53.5	45.79	......	.31	......
772	Scioto	Eifort	.6	1.4		97.32	.45	......	....	......
773	Seneca	Fostoria	......	.28		56.41	41.98	......	.42	......
774	"	"	......	2.7		52	45.26	......	tr.	......
775	"	Tiffin	......	4.86		52.89	33.46	......	5.66	......
776	"	"	......	1.46		79.39	6,2	......	9.88	......
777	"	"	1.61	.1	.07	*a*57.44	*b*40.36	......	....	.41
778	Williams	Bryan	......	1.51		49	38.59	......	9.22	......
779	Wood	Bowling Green	......	.4		53.88	44.91	......	.3	......
780	"	Luckey	.45	.36		54.1	44 9	......	....	......
781	"	Sugar Ridge	......	.69		55.23	43.12	......	.84	......
782	"	Toledo	4.95	.02	....	57.3	36.7	......	....	.21
783	"	"	......	....	....	*a*30.64	*b*18.05	42.82	3.52	......
784	Wyandot	Carey	......	.31		56.4	41.99	......	.48	......
785	"	"	......	3.08		80.11	8.09	......	5.72	......
786	"	Upper Sandusky	......	4.31		64 25	15.93	......	8.18	......

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
751	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke, anal.	Trenton limestone
752	....	" " p. 262; C. Catlett, anal...	Depth 1112 ft
753	....	" " " "	Well no. 2, depth 1065 ft
754	....	" " " "	Doenze's well
755	....	" " p. 261; F. W. Clarke and R. B. Riggs, anal.	
756	Org. .73	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; J. D. Lisle, anal.	J. W. Ruhl quarry
757	P_2O_5 .001	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; Prof. E. Orton, anal.	O. D. Brown "
758	....	U. S. geol. sur. Bul. 148, p. 261......................	Findlay st. well, depth 975 ft
759	....	" 20th rep't, pt 6 cont'd, p. 432.......	N. E. Gregg & Co. quarry
760	....	" Bul. 148, p. 262; C. Catlett, anal....	Trenton limestone
761	....	Ohio geol. sur. 6:734; N. W. Lord, anal............	Newman quarry, Cap rock, Niagara
762	....	" " "	Newman quarry, bottom rock Niagara
763	....	" " "	Wyman & Gregg, main rock, Niagara
764	....	" " "	Habbeler, main rock, Niagara
765	....	" " "	Holt, main rock, Niagara
766	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; Prof. E. Orton. anal	J. Kingham quarry
767	....	U. S geol. sur. 20th rep't, pt 6 cont'd, p. 432; G. A. Kirchmaier, anal.	Duncan & Bussard quarry
768	....	Ohio geol. sur. 5:1109............................	D. Hendricks quarry
769	....	" 6:725; N. W. Lord, anal...........	Dwyer; upper stone
770	....	U. S geol. sur. Bul. 148, p. 262; C. Catlett, anal ..	Waggoner well
771	....	Ohio geol. sur. 6:737; N. W. Lord, anal	H. Rancamp & Co.
772	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432.......	W. E. Marsh quarry
773	....	Ohio geol. sur. 6:739; N. W. Lord, anal............	Niagara limestone
774	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432......	D. P. Lloyd & Co. quarry
775	....	" Bul. 148, p. 262; C. Catlett, anal ..	Loomis & Nyman well
776	....	" " " "	"
777	....	" 20th rep't, pt 6 cont'd, p. 433; O. Wulte, anal.	L. McCollum & Co.
778	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke, anal.	Well no. 3; gas rock
779	....	" 20th rep't, pt 6 cont'd, p. 432; Prof. E. Orton, anal.	Snowflake lime co.
780	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; G. A. Kirchmaier, anal.	N B. Eddy
781	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; Prof. E. Orton, anal.	Sugar Ridge lime and stone co.
782	Org. .32	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; H. Blanck, anal.	Doherty & Co.
783	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke and R. B. Riggs, anal.	Air Line Junction
784	....	U. S. geol sur 20th rep't, pt 6 cont'd, p. 432; Prof. E. Orton, anal.	M. Daum & Son
785	....	U. S. geol. sur. Bul. 148, p. 262; C. Catlett, anal ...	
786	....	" " " "	City well no. 2

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Pennsylvania									
787	Adams.........	Fairfield............	10.3	1.5		85.23	2.78	......	....	......
788	"	"	8.85	......	.6	86.91	3.11	.38	....	......
789	Armstrong.....	N. e. of Kittanning.	.....	1		96.785	1.278	.....	.87	.....
790	Beaver.........	½ m. below Vauport	......	1.823		93.482	1.544	......	2.77	......
791	"	"	......	2.324		88.464	1.445	......	7.03	......
792	"	"	......	1.291		91.607	1.566	......	4.78	......
793	"	"	......	1.589		91.089	1.587	......	4.8	......
794	Bedford	Everett..............	4.48	.89	......	*a*30.18	*b*19.48	......	....	......
795	Berks...........	Esterley	......	1.22		55.58	39.21	......	3.89	......
796	Blair	Near Altoona........	....	.842		95.664	1.547	......	2.5	......
797	"	"	.....	.644		95 089	1.581	......	3	......
798	"	"	.....	.57		95 571	1.521	.....	3.02	......
799	"	Near Birmingham..	......	1.19		53.87	41.32	.....	2.91	......
800	"	6. m. s. w. of Birmingham	......	2.85		48.03	37.67	......	10.38	......
801	"	Catharine township	......	.364		94.98	3.866	......	.91	......
802	"	Frankstown	1.06	....	....	*a*54.9	....	......	....	......
803	"	Hollidaysburg.......	......	.035	......	96.164	1.589	......	1.615	......
804	"	"	.....	.043	....	84.782	3.859	......	10.85	......
805	"	Roaring Spring......	......	1.85		78.176	10.746	.....	8.57	......
806	"	Hollidaysburg.......	......	.054	....	95 251	2.265	......	1.8	......
807	"	Roaring Spring......	......	.64		91.892	2.875	......	4.38	......
808	"	R. R. s. of Roaring Spring	......	.284		54.571	44.18	......	1.33	......
809	....	Sarah furnace quarry	......	.44		96.142	1.604	......	1.688	......
810	....	Springfield furnace quarry	......	1.126		78.196	17.51	......	3.21	......
811	Bradford.......	1 m. e. of Burlington	.....	2.613	4.428	*a*41.048	*b*1.135	33.24	18.01	......
812	Butler..........	West Winfield.......	......	1		95.1	1.12	......	2.78	......
813	Cambria........	Johnstown	.....	3.39	....	34 301	21.65	......	27.873	......
814	Center..........	Near Bellefonte.....	......	& $FeCO_3$	.203	97.89	1.285	......	.54	.. .
815	....	"		"	.32	98.322	1.17	......	.39	......
816	....	"	......	"	.377	97.532	1.21	.....	.815	......
817	Chester..... ..	Downingtown.	......	......	.37	54.15	45.2	......	....	......
818	Cumberland....	Greason..............	.....	....	....	*a*39.36	*b*9	38.82	11.07	.18
819	Fayette	George township....	.....	.543	$FeCO_3$ 1.657	80.647	2.217	......	10.77	1 01
820	....	3 m. n. e. of Uniontown	......	.812	$FeCO_3$ 5.178	66 471	17.711	......	9.46	......
821	....	Uniontown....	......	.135	$FeCO_3$ 1 914	87.868	1.733	......	7.36	......

*a*CaO

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
787	Ign. .19	U. S. geol. sur. 20th rep't, pt 6, p. 441; F. Menger, anal.	W. H. Gelbach
788	....	U. S. geol. sur. 20th rep't, pt 6, p. 441; F. Menger, anal.	G. W. Musselman
789	....	Pa. geol. sur. MM, p. 298..........	Pine Creek furnace quarry
790	....	" p. 297	Severn quarry
791	....	" "	Powers quarry
792	....	" "	"
793	....	" "	Tygart quarry
794	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441........	J. E. Thorpp
795	....	" " " " C. T. Davies, anal.	A. K. Stauffer
796	....	Pa. geol. sur. MM, p. 301	Bakers quarry
797	....	" " "	"
798	....	" " "	"
799	....	" " p. 307	Keystone zinc co. Siluro-Cambrian
800	....	" " "	Borie property, Siluro-Cambrian
801	....	" " p. 306..........	Mt Etna furnace quarry
802	Ign. 43.8	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441.......	J. K. McLanahan jr
803	....	Pa. geol. sur. MM, p. 302	Manning quarry
804	....	" " "	Loop quarry
805	....	" " p. 306..........	Rodman furnace quarry
806	....	" " p. 302..........	Creswell quarry
807	....	" " p. 306..........	Rodman furnace quarry
808	....	" " "	"
809	....	" " p. 302..........	Lower Helderberg
810	....	" " p. 306..........	Cambro-Silurian limestone
811	....	" " G, p. 38..........	W. B. Kline farm
812	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441.......	Winfield mineral co. quarry
813	$FeCO_3$ 8.7 FeS_2 1.268	Pa. geol. sur. MM, p. 295..........	Johnstown cement bed in A. J. Hawes quarry
814	....	" " p. 307..........	Shortlidge quarry, upper bed
815	....	" " "	" middle bed
816	....	" " "	" lower bed
817	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441	J. Copeland quarry
818	Organic .75	" Bul. 148, p. 255; E. A. Schneider, anal.	
819	....	Pa. geol. sur. MM, p. 287..........	Oliphant furnace quarry
820	....	" " p. 289..........	Redstone limestone; Lemont furnace quarry
821	....	" " p. 290..........	Lemont furnace quarry, Pittsburg limestone

*b*MgO

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Penn. (*cont'd*)									
822	Huntingdon....	McAleavys Fort.....	......	1.439		88.687	1.85	......	8.23	......
823	"	Robertsdale.........	......	......	4.536	52.571	2.081	......	42.46	......
824	"	Broadtop............	......	......	5.179	46.232	2.56	......	34.64	......
825	"	Saltillo..............	8.15	1.26	FeO .638	a39.537	b8.821	41.528	....	......
826	"	"	5.32	.55	FeO .576	a47.08	b4.598	42.09	....	.02
827	"	"	33.22	14.066	FeO 3.342	a14.12	b9.571	24.592	....	1.005
828	"	Near Saltillo........	......	& $FeCO_3$ 1.783		89.292	2.557	.....	5.3	......
829	"	"	......	& $FeCO_3$ 1.667		47.3	2.011	......	49.03	......
830	"	Three Springs......	......	.123	$FeCO_3$ 1.642	90.904	2.162	......	5.7	......
831	"	"	......	& $FeCO_3$ .697		94.035	1.965	......	2.33	......
832	"	"	......	& $FeCO_3$ 1.139		91.125	1.572	......	5.04	......
833	"	½ m. s. of Todd post-office	......	.18	$FeCO_3$ .683	92.323	1.089	......	4.64	......
834	Indiana	1½ m. s. w of Five Points	......	3.22		84.125	5.198	......	6.021	......
835	"	1 m. e. of Chambersville	.....	2.12		84.407	2.8	......	9.15	......
836	"	2 m. s. of Jacksonville	.....	1.7		89.821	1.801	......	5.43	......
837	"	1½ m. n. e. of Homer	......	4.19		72.264	6.493	......	14.98	......
838	"	3 m. s. e. Blairsville.	......	6.93		54.768	8.627	......	27.23	......
839	"	¾ m. w. n. w. of Decker's Point	.....	1.96		88.232	1.371	......	8.21	......
840	"	4½ m. e. n. e. of Blairsville	.....	2.63		82.321	8.021	......	5.502	......
841	"	2 m. s. w. of Smithport	......	4.36	$FeCO_3$ 8.078	36.214	16.883	......	32.79	......
842	"	2 m. s. w. of Smithport	......	7.38		58.75	16.005	......	15.06	......
843	"	1 m e. of Blacklick station	......	3.54		78.768	2.421	......	13.79	......
844	"	½ m s. w. from Richmond	.....	2.03		92.857	1.589	......	2.09	......
845	"	Blairstown	....	5.71		65.892	9.686	......	16.54	......
846	"	Smiths station	......	3.02		79.821	3.601	......	12.16	......
847	"	West Lebanon	.....	2.83		82.768	2.875	......	10.327	......
848	Lancaster.	Chickies............	.36	.31	......	51	48.49	......	....	......
849	"	Rheems	......	.11		97.95	.98	......	.96	......
850	Lawrence	Near Wampum, Big Beaver township	.....	.805		94.214	1.732	......	2.79	......
851	"	3 m.n.w. Mt Jackson, n. Beaver township	......	.632		95.768	1.097	......	1.97	......
852	"	Near New Castle....	......	1.563		93.34	1.46	......	3.07	......
853	"	2 m. n. of Croton....	......	1.187		94.785	1.369	......	2.08	......
854	"	Youngstown	1.5	1.6		96.43	.4	......	....	......
855	Lebanon.........	Richland station....	.07	.19		99.02	.67	......	....	......
856	"	"	.39	.24		98.36	.91	....	....	......
857	Lehigh	Trexlertown	7.22	2.3		86.5	1.21	......	....	......
858	Mifflin...........	2 m. from Belleville.	......	.426		97.651	1.131	......	.76	......

*a*CaO *b*MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
822	....	Pa. geol. sur. MM, p. 366	John Barr quarry
823	....	" " p. 367	Calcareous conglomerate
824	....	" " "	J. Diggins farm
825	....	" " p. 303	375 feet above bottom of Waterlime formation
826	....	" " "	190 feet above bottom of Waterlime formation
827	....	" " "	160 feet above bottom of Waterlime formation
828	....	" " "	125 feet from bottom. C. R. McCarthy
829	....	" " "	Specimen from flinty beds
830	....	" " p. 302	Hudson quarry, 70 feet above bottom of formation
831	....	" " "	Hudson quarry, 60 feet above bottom of formation
832	....	" " "	Hudson quarry, 50 feet above bottom of formation
833	....	" " p. 299	J. Whitney quarry
834	....	" " p. 292	S. Brown quarry; Freeport upper limestone
835	....	" " "	Groft Bros. quarry; Freeport upper limestone
836	....	" " "	S. C. Hazlett quarry; Freeport upper limestone
837	....	" " "	D. R. Griffith quarry
838	....	" " "	G. Livengood quarry
839	....	" " p. 293	S. Palmer quarry; Freeport lower limestone
840	....	" " "	P. Brown quarry
841	....	" " p. 294	A. Gorman, upper layer, Johnstown cement rock
842	....	" " "	A. Gorman, lower layer
843	....	" " "	Tyhawk quarry, main bench
844	....	" " p, 298	Isaac Simpson's
845	....	" " p. 366	G. M Doty
846	....	" " p. 288	Sewickley limestone
847	....	" " p. 289	A. H. Fulton quarry, Pittsburg limestone
848	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441	Chickies iron co.
849	....	" " " "	W. L. Heisey & Co.
850	....	Pa. geol. sur. MM, p. 297	J. K. Shinn & Bros. quarry
851	....	" " "	McCord quarry
852	....	" " "	Green's, Marqu's & Johnson quarries
853	....	" " "	Moffit quarry
854	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441	Carbon limestone co.
855	....	" " " " A. S. McCreath, anal.	J. C. Fisher
856	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; A. S. McCreath, anal.	S. A. Royer
857	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; H. R. Hartzel, anal.	I. Stettler
858	....	Pa. geol. sur. MM. p. 308	D. Campbell quarry

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Penn. *(cont'd)*									
859	Mifflin..........	A. Campbell quarry.	......	1.253		81.178	13.398	......	4.53	......
860	"	"	......	1.36		70.214	24.415	......	4.05	......
861	"	1 m. from Belleville.	......	1.422		54.285	36.109	......	8.01	......
862	"	Reedsville..........	1.69	1.26		95.75	2.03	......	....	......
863	"	"	.33	.61		96.24	2.86	......	....	......
864	Montgomery	Bridgeport L	2.95	1.35		*a*58.33	*b*37.37	......	....	......
865	"	"	1.58	.72		55.7	41.97	....	....	......
866	"	Norristown..........	......	.45		53.49	45.76	......	.2	......
867	"	"	....	.2		54.04	45 51	......	.25	......
868	Northampton....	Freemansburg	2.18	1.61	.32	89.09	5.16	.....	....	......
869	Northumberland	Dalmatia L	......	6.8		*a*81.38	*b*.34	......	2.43	......
870	Somerset........	Buckstown	.....	3.317	$FeCO_3$ 3.069	51.921	3.639	......	37.94	......
871	"	Forwarsdtown	......	.455	$FeCO_3$ 3.314	80.588	8.445	......	4.803	1
872	"	Listie	.....	2		92.12	2.35	......	3.53	......
873	"	2½ m. s. w. of Meyersdale	......	.972	$FeCO_3$ 2.239	72.6.3	12.614	......	9.18	......
874	"	¾ m. w. of Meyersdale	......	1.366	$FeCO_3$ 3.935	69.16	15.535	......	9.73	......
875	"	1 m.w. of Meyersdale	.....	2.886	$FeCO_3$ 6.835	55.589	14 224	......	19.8	......
876	"	1 m. n. of Salisbury.	......	1.548	$FeCO_3$ 5.282	74.803	6.734	......	11.51	......
877	"	2½ m s. of Salisbury.	......	& $FeCO_3$ 1.825		86.625	6.152	......	4.04	......
878	"	2½ m. n. of Salisbury	......	1.7	$FeCO_3$ 4.274	64.706	2.156	......	20.66	......
879	"	¾ m. n. of Ursina...	......	& $FeCO_3$ 1.986		90.803	2.738	......	3.74	......
880	"	3½ m. s. e. of Somerset	......	& $FeCO_3$ 4.393		63.969	4.244	......	24.78	......
881	"	1¼ m. s e. of Friedensburg	......	& $FeCO_3$ 2.972		86.778	2.908	......	6.04	......
882	"	Sipesville............	......	& $FeCO_3$ 3.693		79.478	10.222	......	4.97	......
883	"	Stoystown	......	.34	$FeCO_3$ 1.798	88.139	1.854	......	5.64	......
884	"	Jenner Crossroads..	......	.359	$FeCO_3$ 1.167	92.298	1.483	......	3.95	......
885	"	" ..	......	1.626	$FeCO_3$ 8.492	54.321	23.088	......	12.02	......
886	"	" ..	......	.403	$FeCO_3$ 4.739	69.261	13.773	......	10.76	......
887	"	Huskins run; Shade township	......	4.44	$FeCO_3$ 5 8	52.94	16.06	......	17.77	......
888	"	Near Davidsville....	......	.261	$FeCO_3$ 1.503	90.544	2.134	.....	3.85	......
889	"	¾ m. n. of Scalp Level	......	& $FeCO_3$ 11.6		50.16	18.494	......	13.36	......
890	Sullivan.........	Near Millview.......	......	5.196		80.393	5.653	......	5.24	......
891	"	"	......	5.87		69	5.387	......	17.85	......
892	Tioga...........	½ m. n. of Mansfield.	......	2.269	2.142	*a*28.872	*b*1.117	23.227	41.7	......
893	Washington.....	1 m. e of Washington	......	2.929		72.866	3.813	......	17.38	......

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
859	....	Pa. geol. sur. MM, p. 308	Probably top of Calciferous
860	....	" " "	Bottom of Chazy.............
861	....	" " "	Greenwood ore bank limestone
862	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; R. Kent, anal.	J. B. Smith no. 1
863	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; R. Kent, anal.	" 2
864	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; C. F. Reader, anal	R. McCoy lime co.
865	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441.......	"
866	....	" " " " Booth, Garrett & Blair, anal.	W. B. Rambo, quarry no. 1
867	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; Booth, Garrett & Blair, anal.	" " 2
868	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; A. Bachman, anal.	G. W. Bachman
869	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; Dr W. Frear, anal.	J. Yeager
870	....	Pa. geol. sur. MM, p. 366............................	Burkit farm
871	....	" " "	Harshberger quarry
872	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441.......	Listie mining co.
873	....	Pa. geol. sur. MM, p. 286	Keystone coal and mfg. co. quarry
874	....	" " p. 287............................	Saylor Hill quarry
875	....	" " p. 291.........................	Yoder's quarry
876	....	" " p. 287............................	J. M. Hayes quarry
877	....	" " p. 289............................	M. J. Beechy quarry; Redstone limestone
878	....	" " p. 290	S. S. Flickenger quarry
879	C 2.602	" " p. 291............................	Pittsburg coal, coke and iron co. Elklick limestone
880	....	" " p. 295............................	Johnstown cement rock in Zimmerman quarry
881	....	" " "	Reitz quarry
882	....	" " "	J. J. Pile quarry
883	....	" " "	Wilt quarry
884	C .55	" " "	J. H. Beans upper bench
885	C .98	" " "	" middle bench
886	C .59	" " "	" lower bench
887	....	" " p. 296............................	D. Rodgers quarry
888	....	" " "	Trevorrow quarry, Johnstown
889	....	" " "	J. Weaver quarry, Johnstown
890	....	" " p. 300	Lucke quarry upper bench
891	....	" " "	" lower bench
892	....	" " p. 299............................	G. R. Wilson
893	....	" " p. 284............................	

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Penn. (*cont'd*)									
894	Washington....	1 m. n. of Cannonsburg	......	&$FeCO_3$ 3.306		68.867	14.649	......	13.3	......
895	"	1 m. n. of Cannonsburg	......	.... 3.523	$FeCO_3$ 3.625	48.823	20.621	......	22.52	......
896	"	1 m. n. of Cannonsburg	......	&$FeCO_3$ 7 511		47.08	28.528	......	15.75	......
897	"	8 m. from Washington	......	&$FeCO_3$ 5.608		47.75	30.943	......	14.92	......
898	Westmoreland.	½ m. w. of Kelly's station	......	1.52		91.982	1.664	......	4.015	......
899	"	Salina	......	2.72		94.643	1.144	....	.99	......
900	"	7 m. from Mt Pleasant	......	6.002	$FeCO_3$ 4.142	42.357	4.037	....	38.24	......
901	York	½ m. w. of Mengis Mill station	.....	1.138	.896 FeO 2.443	*a*36.816	*b*5.019	35.55	16.65	.35
902	"	½ m. w. of Mengis Mill station	......	1.93	5 524 FeO 2.228	*a*38.5	*b*.814	31.632	18.21	1.055
903	"	Wrightsville	.56	.66		154.26	44 51	......	....	......
904	"	Hellam	.12	.14		93.14	6.51	......	....	......
	Rhode Island									
905	Providence. ..	Lime Rock..........	......	.309	.011	88.233	8.797	......	2.748	.04
	South Dakota									
906	Lawrence	Deadwood	......	tr.		*a*33.8	*b*15.7	......	1.8	......
	Tennessee									
907	Franklin	Sherwood L	.56	.22		*a*97.89	1.05	......	....	......
908	Houston........	Erin L	......	.13	.23	*a*97.82	*b*.12	......	.43	......
909	Knox	Knoxville	.17	.04	.23	*a*55.47	*b*.3	43.63	....	.21
	Texas									
910	Coryell.........	Oglesby...............	......	....	.35	*a*54.02	*b*.12	43.96	1.09	......
911	Travis	McNeil L	......	.15 .16		*a*97.46 *a*97.82	....	......	.25 .15	und. .73 und. .85
	Vermont									
912	Addison	Leicester Junction.L	.383	....	.647	*a*98.262	*b*.299	......	....	......
913	Bennington	North Pownal L	.27	.11	.08	*a*98.14	*b*1.4	......	....	......
914	Franklin	Highgate Springs...	.4	.1		*a*55.83	*b*tr.	43.65	....	......
915	"	St Albans..........L	......	tr.	tr.	*a*99.23	*b*.6	......	.14	......
916	"	Swanton...........L	tr.	....	tr.	*a*98.47	1.12	.45	....	......
917	"	" L	.1	tr.	......	*a*99.29	.46	....	....	......
918	"	" L	.02	....	....	*a*98.84	.12	1.02	....	......
919	Rutland........	Proctor	......	.2		*a*55	*b*.25	44.02	.35	......
920	"	"	......	....	$FeCO_3$ .053	96.3	3.06	......	.63	......
921	"	"	......	....	$FeCO_3$ .034	98.37	.79	....	.63	......
922	"	West Rutland.......	......	.3		*a*55.27	*b*.28	43.82	.28	......
923	"	"	......	.2		*a*55.26	*b*.15	43 66	.4	......
924	"	"	......	.15		*a*55.50	*b*tr.	43.65	.7	......

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
894	....	Pa. geol. sur. MM, p. 285	Uniontown limestone, lower division, upper layer
895	....	" " "	Uniontown limestone, lower division, middle layer
896	....	" " "	Uniontown limestone, lower division, bottom layer
897	....	" " "	Uniontown limestone, Shaner property
898	....	" " p. 293	Wining & Cuisan quarry
899	....	" " "	Kier Bros. quarry
900	....	" " p. 367	J. Freeman
901	....	" " p. 308	
902	....	" " "	
903	....	U. S. geol. sur. 20th rep't pt 6 cont'd, p. 441........	Steacy & Co. quarry
904	....	" " " "	"
905	....	" " "p. 442; J. H. Appleton, anal.	H. Harris quarry
906	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 443; J. V. N. Door, anal.	Deadwood & Delaware smelting co.
907	....	U. S. geol sur. 20th rep't, pt 6 cont'd, p. 444........	Gager lime and mfg. N. co.
908	....	" " " p. 443	Arlington lime co.
909	....	" Bul. 148, p. 258; L. G. Eakins, anal.	
910	SO_3 .17 Org .52	" 20th rep't, pt 6 cont'd, p. 444; H. H. Harrington, anal.	D. R. Boone quarry
911		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 444........	Austin White lime co. analysis of lime
		" " " "	Austin White lime co.
912	....	" " " p. 455........	Brandon lime and marble co.
913	....	" " " " R. Shuppaus, anal.	Follet Bros.
914	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 456; S. P. Sharpless, anal.	L. H. Felton
915	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 456; F. C. Robinson, anal.	W. B. Fonda
916	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 455.	J. P. Rich, no. 1
917	FeO .12	" " " "	" 2
918	....	" " " "	" 3
919	Org. none	" 18th rep't, pt 5 cont'd, p. 986........	Marble
920	Org. .004	" " " "	Light marble
921	MnO_2 .005 Org. .08	" " " "	Dark "
922	....	" " " p. 985.......	Blue "
923	....	" " " "	White "
924	....	" " " "	Statuary "

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Vermont (*con.*)									
925	Rutland	West Rutland.......	......	....	....	*a*55.15	*b*.57	44	.22	......
926	"	"	.....	....	....	*a*54.95	*b*.59	43.8	.62	......
	Virginia									
927	Augusta	Staunton	7.37	1.92	.29	*a*28.39	*b*18.3	41.85	....	.49
928	Frederick	Winchester	2.68	1.68		80.6	14.48	......	....	.56
929	"	N. w. turnpike, w. of Winchester	1.3	.12		88.64	9.6	......	....	.44
930	Montgomery ...	2 m. from Christiansburg road to Blacksburg	6.5	.84		55.8	*a*35.34	......	....	......
931	" ...	N. mountain, Price's road	7.44	1.16		52.2	38.4	......	....	.8
932	Orange.........	1½ m. from Gordonsville	19.6	.8		79.2	tr.	......	....	.4
933	"	5 m. from Gordonsville	3.28	1.28		51.72	42.72	......	....	1
934	Page............	....	1.48	1.6		70.16	25.96	......	....	.8
935	"	Luray	5.5	.77		78	11.37	......	....	4.86
936	"	Shenandoah	5.4	.8		47.48	45.8	......	....	.56
937	Shenandoah....	½ m. w. of New Market	4.5	.84		86.16	....	......	....	6.5
938	"	New Market	7 6	.23		81	10.6	......	....	.52
	West Virginia									
939	Berkeley	Marlowe L	.....	.26		*a*98.44	*b*.98	.32	.18	......
940	Grant.	Knobly mountain...	4.56	.72		90.08	4	......	....	.64
941	"	Near Petersburg	6	1.52		88.52	3.24	......	....	.72
942	Greenbrier......	Fort Spring	......	2.02		90.11	2.49	......	5.04	.34
943	"	On C. & O R. R......	......	1.12		93.76	.29	......	3.92	.91
944	" .. .	Blue Sulphur Springs	.4	.48		98.2	....	......	....	.24
945	"	Muddy Creek mountain	1.2	.12		88.64	9.6	......	....	.44
946	"	Snow Flake	......	1.46	....	96.46	1.11	......	.97	......
947	Harrison........	Near Clarksburg....	.72	.96		95.52	1.88	......	.92	......
948	Jefferson.......	Harpers Ferry	6.68	.52		81.16	10.8	......	....	.84
949	"	2 m. s. w. Harpers Ferry	1.68	.48		53.88	43.4	.....	....	.56
950	"	4 m s. w. Harpers Ferry	......	tr.		95.86	1.46	......	1.83	.85
951	"	Charlestown.........	42.5	1.5	2	38.66	9.5	......	....	5.84
952	"	Shepherdstown......	38.93	4.17		32.17	18.36	......	....	......
953	"	"	42.9	2.1		23.9	24.36	......	....	6.74
954	"	"	12.6	7		67.5	8.36	.....	....	4.54
955	Kanawha	Two Mile creek	1.76	.8		83.92	2.8	......	....	.72
956	"	"	1.6	1.6		96.2	tr.	......	....	.6
957	"	Big Buffalo creek...	18.48	2.16		73.44	5.32	.....	....	.6
958	"	Little Buffalo creek.	18.72	1.4		72.52	6.8	......	....	.56
959	"	Eighteen Mile creek	31.92	3.68		55.96	7.6	......	....	.84

*a*CaO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
925	....	U. S. geol. sur. 18th rep't, pt 5 cont'd, p. 985; J. M. Harris, anal.	Blue marble
926	....	U. S. geol. sur. 18th rep't, pt 5 cont'd, p. 985; J. M. Harris, anal.	White marble
927	Alkalis 1.18 FeO .63	U. S. geol. sur. Bul. 148, p. 256; G. Steiger, anal...	
928	....	W. B. Rogers. Geol. of Va. p. 521................	
929	....	" " p. 522................	
930	....	" " p. 170................	
931	....	" " p. 523................	
932	....	" " p. 520................	
933	....	" " p. 520................	
934	....	" " p 521................	
935	....	" " p. 170................	
936	....	" " p. 522................	
937	....	" " p. 170................	
938	....	" " p. 522................	
939	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 459........	G. C. & S. C. Ditto
940	....	Description of resources of W. Va. Summers 1893, p. 88; W. B. Rogers, anal.	
941	....	Description of resources of W. Va. Summers 1839, p. 150; W. B. Rogers, anal.	
942	....	Description of resources of W. Va. Summers 1839, p. 150; W. B. Rogers, anal.	
943	....	Description of resources of W. Va. Summers 1839, p. 150; W. B. Rogers, anal.	C. E. Dwight
944	....	Description of resources of W. Va. Summers 1839, p. 150; W. B. Rogers, anal.	
945	....	Description of resources of W. Va. Summers 1839. p. 150; W. B. Rogers, anal.	
946	Org. tr.	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 460; J. B. Britton, anal.	D. Y. Huddlestone
947	....	Description of resources of W. Va. Summers 1893, p. 88; W. B. Rogers.	
948	....	Description of resources of W. Va. Summers 1893, p. 88; W. B. Rogers.	
949	....	Description of resources of W. Va. Summers 1893, p. 88; W. B. Rogers.	
950	....	Description of resources of W. Va. Summers 1893, p. 88; W. B. Rogers,	
951	....	Geol. of Va. 1839, p. 170	On road to Locke's tavern
952	....	" " p. 138............................	Reynold's quarry
953	....	" " p. 169	"
954	....	" " "	"
955	....	" " p. 524.	Lower bed
956	....	" " "	Upper bed
957	....	" " p. 525............................	
958	....	" " "	
959	....	" " "	3 m. from mouth

*b*MgO

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	West Va. (*con.*)									
960	Kanawha........	Coal river, lowest falls	1.68	.48		83.96	13.2	......	....	.68
961	"	Tyler's creek........	17	5.2		75.8	tr.	......	....	2
962	Mason	Point Pleasant......	9.68	3.52		79.84	6.28	......	....	.68
963	Marshall.......	Moundsville narrows	1.53		.96	*a*53.26	*b*.93	43.16	....	.1
964	"	"	10.33		.9	*a*48.02	*b*1.08	39.18	....	.05
965	Mineral.........	Patterson's creek...	4.96	.76		92.44	1.4	......	....	.68
966	Monongalia.....	Greenville Furnace.	7.64	2.52		88.32	....	......	....	.76
967	Monroe.........	Red Sulphur Springs	6.2	1.2		90.92	tr.	.....	....	.44
968	"	Union	1.88	.56		95.92	....	......	....	.4
969	"	Dunlaps Creek......	2.96	.52		86.52	9.52	....	....	.48
970	"	Little North mountain	10.8	1		78 48	9.2	....	....	.52
971	Ohio	Willow grove..	7.61	4.1		85.95	1.38	....	....	.96
972	Pleasants	South side Rapidanne river	2	.52		90.4	6.44	......	....	.64
973	Preston	Jenkins lime kiln....	5.8	1.16		89 76	2.32	......	....	.92
974	....	R. Forman's........	1.36	.4		91.8	5.72	....	....	.76
975	....	Below coal no. 2	.....	3.12		79.52	2.8	......	13.8	1.24
	Wisconsin									
976	Calumet	Brillion..	.59	.36	....	55.09	43.96	......	....	......
977	Dodge	Knowles	..	.24		54.3	45.32	......	.28	......
978	Door	Sturgeon Bay	1.09	.33		54 42	44.17	......	....	......
979	Fond du Lac...	Hamilton	......	.1	.26	54 25	44 48	......	.67	.11
980	Milwaukee	Milwaukee	17.56	1.41	3 03	45.54	32.46	......	....	......
981	"	"	17.56	1.4	2.24	48.29	29.19	....	....	......
982	"	"	16.99	5	1.79	41.34	34.88	....	....	......
983	Outagamie. ..	Duck Creek.........	3.17	1 95		49 97	44.58	.....	....	.....
984	Ozaukee........	Grafton	.37	.92		52.57	45.34	.....	.62	......
985	Sheboygan	Sheboygan..........	.46	1.1		55 49	42.31	.64	....	.....
986	Waukesha	Genesee	6 82	1.02		50.96	41.75	....	....	.....
987	"	Lannon	3.96	1.68		52 29	42.27	....	....	......
988	Winnebago	....	3.01	1.82	.18	51.97	42.91	......	....	....

a CaO

THE UNITED STATES *(concluded)*

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
960	....	Geol. of Va. p. 525; W. B. Rogers, anal............	
961	....	" " "	
962	....	" " "	
963	....	U. S. geol. sur. Bul. 148, p. 256; T. M. Chatard, anal.	Lower ledge
964	....	" " " "	Upper "
965	....	Geol of Va. p. 520; W. B. Rogers, anal...........	
966	....	" " "	
967	....	Description of resources of W. Va. Summers 1893, p. 88; W. B. Rogers	
968	....	Description of resources of W. Va. Summers 1893, p. 88; W. B. Rogers	
969	....	Description of resources of W. Va. Summers 1893, p. 88; W. B. Rogers	
970	....	Description of resources of W. Va. Summers 1893, p. 88; W B. Rogers	
971	....	Geol. of Va. p. 520; W. B. Rogers, C. E. Dwi anal.	
972	....	Geol. of Va. p. 520; W. B. Rogers, C. E Dwight, anal.	Gibson's quarry
973	....	Geol. of Va. p. 520; W. B. Rogers, C. E. Dwight, anal.	
974	....	Geol. of Va p. 520; W. B. Rogers, C. E. Dwight, anal.	
975	....	Geol. of Va p. 529; W. B. Rogers, C. E. Dwight, anal.	
976	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 462; Gustave Bode, anal.	Ormsby lime co.
977	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 462; W. W. Daniells, anal.	Nast Bros. quarry
978	....	Wis. geol. sur. Bul. 4, p. 420; W. W. Daniels, anal..	" "
979	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 463; W. W Daniells, anal.	Hamilton stone and lime co.
980	....	Ark. geol. sur. 1890, 4: 122.........................	Cement
981	....	" " "	
982	....	" " "	
983	....	Wis. geol. sur. Bul. 4, p. 420; W. W. Daniells, anal.	
984	Alkalis .8	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 462.....	Milwaukee Falls lime co.
985	....	" " " " p. 463; G. Bode, anal.	Sheboygan lime works.
986	....	Wis. geol. sur. Bul. 4, p. 420	
987	....	U. S. geol. sur., 20th rep't, pt 6 cont'd, p. 463	
988	....	Min. res. 1889-90, p. 439; J. C. Jack, anal............	

*b*MgO

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The superior figures tell the exact place on the page in ninths; e. g. 696^3 means page 696, beginning in the third ninth of the page, i. e. about one third of the way down.

MUSEUM BULLETIN 44, PLATE 1

Map of New York state showing location of limestone quarries and marl deposits and manufactories of natural and Portland cement

MUSEUM BULLETIN 44, PLATE 103

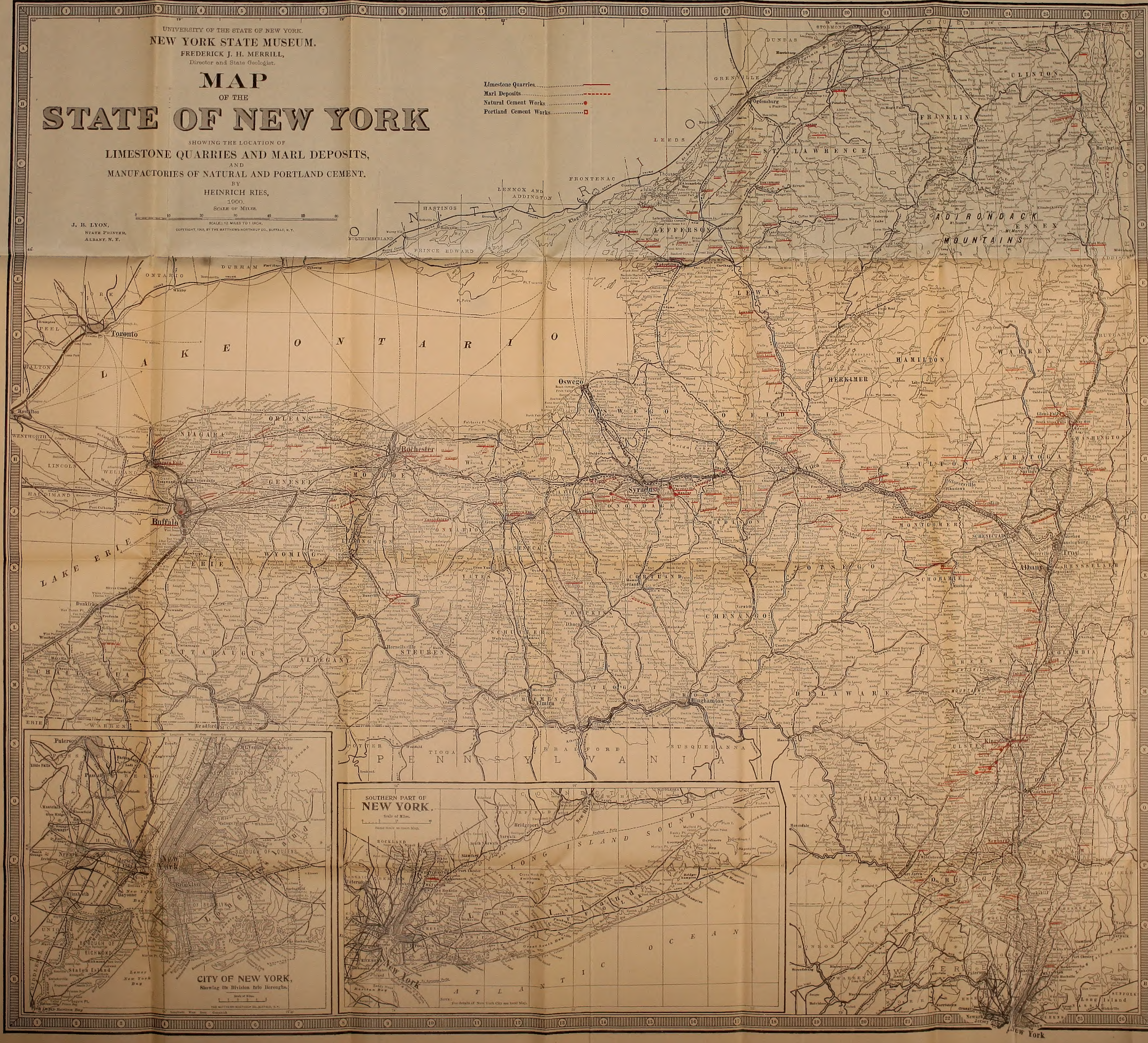
Map of New York state showing the distribution of limestones

FREDERICK J. H. MERRILL
Director and State Geologist

UNIVERSITY OF THE STATE OF NEW YORK
NEW YORK STATE MUSEUM

BULLETIN No. 44.

JAMES B. LYON, STATE PRINTER


UNIVERSITY OF THE STATE OF NEW YORK.
NEW YORK STATE MUSEUM.
FREDERICK J. H. MERRILL,
Director and State Geologist.
MAP
OF THE
STATE OF NEW YORK
SHOWING THE LOCATION OF
LIMESTONE QUARRIES AND MARL DEPOSITS,
AND
MANUFACTORIES OF NATURAL AND PORTLAND CEMENT.
BY
HEINRICH RIES,
1900.
Scale of Miles.
J. B. LYON,
State Printer,
Albany, N. Y.
Limestone Quarries
Marl Deposits
Natural Cement Works
Portland Cement Works
LAKE ONTARIO
LAKE ERIE
ADIRONDACK MOUNTAINS
PENNSYLVANIA
SOUTHERN PART OF
NEW YORK.
CITY OF NEW YORK,
Showing its Division into Boroughs.

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